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OCEAN DISPOSAL OF BARGE-DELIVERED LIQUID AND SOLID WASTES FROM U.S. COASTAL CITIES

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Dillingham Corporation

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OF BARGE-DELIVERED LIQUID AND SOLID WASTES FROM U.S. COASTAL CITIES

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This publication (SW-19c) was written for the
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U.S. ENVIRONMENTAL PROTECTION AGENCY
Solid Waste Management Office

1971

FOREWORD

WHAT GOES INTO THE SEA is everybody's business. At present, solid and liquid wastes are being shipped to sea for disposal in such quantities that marine disposal has become an important subject for investigation. These barged wastes are the ones that would place a heavy burden on the land if they were discharged to community sewer systems, to streams, or to the land surface, and thus are those for which the cost of sea disposal is accordingly attractive.

With increasing restrictions on air and water pollution, and as land disposal activities are upgraded, communities and industry have been looking more to the sea for ultimate disposal of their wastes. On contract to the Federal solid waste management program, the Dillingham Corporation has completed a baseline survey of the subject. This study provides an inventory of: the composition, amounts, and origins of wastes regularly transported by ships or barges to offshore disposal areas from principal U.S. coastal cities; the characteristics of disposal areas and observed effects of waste disposal on the marine environment; the Federal, State, or municipal agencies currently responsible for regulation and surveillance of present disposal activities; recommendations for activities to be undertaken in the area.

This is just the beginning of a body of information that must be accumulated and studied before we will know whether or not we can use the ocean as a waste receptacle and still protect it as a resource. The opinions expressed by the authors, as well as mention of any commercial products, in no way imply endorsement by the U.S. Environmental Protection Agency.

—RICHARD D. VAUGHAN
Deputy Assistant Administrator
for Solid Waste Management

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SUMMARY

In 1968, approximately 62 million tons of wastes were disposed of in the ocean at an estimated cost of $37 million. Most of this was spoil from U.S. Army Corps of Engineers' harbor dredging operations, which accounted for more than 52 million tons and $23.5 million. Industrial waste tonnage and costs ranked second with 4.7 million tons discharged at a cost of nearly $8 million. Sewage sludge was third with 4.5 million tons at $4.4 million (all tonnages are on a wet basis).

During the period June 1968 through October 1969, the Dillingham Corporation conducted a field and literature study on the oceanic disposal by barge of solid and liquid wastes from 20 United States cities. This work was carried out under contract (PH 86-68-203) with the Solid Waste Management Office, U.S. Environmental Protection Agency. Objectives of the study were to inventory present disposal practices, evaluate regulatory monitoring and available information on environmental effects, summarize the legal framework within which the operations are conducted, to identify problem areas, and to make appropriate recommendations.

The 20 cities considered in the survey included Seattle, Portland (Oregon), San Francisco, Los Angeles, San Diego, Galveston, Texas City, Houston, Port Arthur, Beaumont, New Orleans, Pascagoula, Mobile, St. Petersburg, Charleston, Norfolk, Baltimore, Philadelphia, New York, and Boston.

In addition to the specific waste categories indicated above, refuse and garbage accounted for 26,000 tons; construction and demolition debris–574,000 tons; outdated military explosives and chemicals–15,200 tons; and miscellaneous–200 tons. There was no sea disposal of radioactive wastes from the United States in 1968, although European nations still use this method. The United States resumed the disposal of radioactive wastes in 1969.

Of the waste categories studied, the industrial discharges are the most significant. In 1968, these included 2.7 million tons of waste acid; 560,000 tons of refinery wastes, 330,000 tons of pesticide wastes; 140,000 tons of paper mill wastes; and 940 tons of other materials. Although most industrial wastes originate from the coastal areas, increasing amounts from interior areas of the Nation are barged to sea. More than half the total pesticide wastes originate within the Mississippi Valley, and one proposal was made for the marine discharge of industrial wastes from the upper Ohio basin in West Virginia.

Unit costs of disposal range from $0.20 per ton for dredge spoil to $600 per ton for miscellaneous wastes. Sewage sludge was disposed of for $0.80 to $1.20 per ton ($18 to $27 per ton dry weight). Industrial waste costs ranged from $0.60 per ton for bulk shipments to $130 per ton for containerized wastes.

The environmental consequences of barging wastes to sea are not known, although a few pioneer efforts have been made to determine short-term effects of industrial discharges, and major studies are currently underway to evaluate long-term consequences of marine disposal of sewage sludge. Certain inert waste materials may be used to advantage in water; discarded automotive bodies and tires have been used for artificial fishing reefs. It has been proposed that other structural uses of solid wastes be investigated, including artificial islands, breakwaters, and offshore bars (the latter to develop breakers and improve surfing). The rather speculative suggestion that baled municipal refuse could provide both shelter and food for marine fish has been made; experience with environmental damage near the sewage sludge dumping grounds in the New York Bight indicates that much research, development, and demonstration is required before this method of recycling waste materials could be considered on a significant scale.

The recycling of materials is becoming accepted as a national goal that would conserve all resources, including environmental ones. Meanwhile, coastal communities have the immediate problem of increasing solid waste disposal requirements and increasing competition for funds. Until recycling becomes a reality, many of these communities may look to the sea for disposal, and the potential effects of proposed discharges therefore must be known.

Monitoring and data management for present marine disposal operations are unsatisfactory because of lack of funds, personnel, and clear-cut responsibility. There is existing legislation that provides for regulating waste disposal activities resulting in pollution within the territorial sea and inland waters of coastal States. There is, however, no provision for specific procedures to control and enforce disposal requirements beyond the 3-mile limit. Within the provisions of existing inadequate law and regulation, the U.S. Army Corps of Engineers provides such guidance as exists. There are variations in effectiveness in controlling barge disposal of wastes in different Corps of Engineer districts. These result from inadequacies in Federal law. The formation of the U.S. Environmental Protection Agency in December 1970 provides hope for control and guidance in the area of marine disposal.

In order to conserve and utilize the environmental and other resources of the sea, it is recommended that:

1. The Federal Government, in conjunction with the coastal States, evaluate existing conventions, treaties, laws, and regulations pertaining to marine waste disposal and adopt appropriate legislation and regulations to establish an effective legal framework.
2. The Federal Government establish uniform application and review procedures for marine waste disposal permits and minimum standards for baseline surveys, monitoring procedures, and related data management and dissemination.
3. The Federal Government support and participate in environmental research leading to effective functional designs and operating criteria for beneficial or nondamaging disposal of wastes into the marine environment and to specifically probe those items known to cause environmental problems.
4. The Federal Government support engineering research, development, and demonstration of marine waste disposal systems, those classes of wastes which do not damage the environment. This should include optimization of materials handling, processing, and transportation facilities and monitoring systems and procedures.

ocean disposal OF BARGE-DELIVERED LIQUID AND SOLID WASTES FROM U.S. COASTAL CITIES

THIS REPORT summarizes the results of a field survey of twenty U.S. coastal cities to appraise the national status of oceanic disposal of solid wastes and industrial sludges from ships and barges. The work was carried out by the Applied Oceanography Division of the Dillingham Corporation during June 1968 to October 1969, under contract with the Solid Waste Management Office, EPA. The inventory of solid wastes and industrial sludges included construction and demolition debris, dredge spoils, sewage sludge, and spent acids. The cities considered in this inventory were Seattle, Portland (Oregon), San Francisco, Los Angeles, San Diego, Galveston, Texas City, Houston, Port Arthur, Beaumont, New Orleans, Pascagoula, Mobile, St. Petersburg, Charleston, Norfolk, Baltimore, Philadelphia, New York, and Boston.

BACKGROUND

In general, disposal of waste materials at sea begins with an application to the District Office of the U.S. Army Corps of Engineers. This application is then circulated by the Corps to the other Federal (and, in some cases, State) agencies concerned with various aspects of water quality, including public health, recreation, fisheries, etc., for review and comment. If the various agencies are reasonably agreeable, the Corps issues a "letter of no objection," which, in essence, is an authorization to undertake the disposal operation. In addition, the Corps may specify certain regulatory procedures to be followed in connection with the proposed disposal activities. This process will be radically changed when applications are screened by the Environmental Protection Agency.

Because of increasingly strict water and air pollution laws, the loss of land areas now used for solid waste landfill and ponding of liquid wastes and the anticipated growth in population and industry within our coastal cities over the next 10 years, it can be predicted that the disposal of wastes at sea will increase materially or be stopped in the future. In this regard, some major cities (including San Francisco and Philadelphia) have already shown substantial interest in proposed programs for sea disposal of municipal refuse; such considerations may be completely altered by regulations from the U.S. Environmental Protection Agency.

OBJECTIVES

The objectives of the study were: (1) to determine the nature and magnitude of present oceanic disposal practices from major U.S. coastal cities; (2) to evaluate what is known regarding the effects of these wastes on the marine environment, and particularly, the biota; and, (3) to summarize the legal framework under which these disposal operations are carried out; (4) to determine the status of regulatory monitoring of these operations; (5) to identify those aspects of marine disposal which are problem areas and make appropriate recommendations.

APPROACH

Because of the key position of the Corps of Engineers, initial contact points were the various District Offices of the Corps. Interviews with the

District Offices' personnel responsible for issuing "letters of no objection" provided background information on marine disposal operations in their respective areas of control. This background information provided the basis for planning and carrying out a series of interviews with waste producers, disposal operators, and pertinent municipal, State, and Federal agencies. A comprehensive questionnaire (Appendix A) regarding marine waste disposal activities was utilized as a guide for conducting and recording each interview. Integrity of proprietary information was maintained. For large industrial firms producing wastes destined for sea disposal, the usual procedure was to carry out an initial interview, leave a copy of the questionnaire (or mail it to the industrial firm) for subsequent completion and return. This procedure was useful because the individuals interviewed generally did not have the details of the disposal operations immediately available. With few exceptions, questionnaires handled in this fashion were completed and returned with a minimum of delay.

SPECIAL REVIEW PANEL

In order to insure an objective evaluation of the results of the Dillingham city-by-city field survey program, the Applied Oceanography Division arranged a one-day special panel meeting in La Jolla, California, on 17 July 1969, where representatives of regulatory and resource agencies, the research community, various interested industrial firms, and the Bureau of Solid Waste Mangement reviewed the findings. The specific objectives of this meeting were to critically evaluate each of the principal classes of wastes currently being discharged in U.S. coastal waters in terms of: engineering and economic acceptability of present disposal methods; present status of environmental monitoring to determine the effects that the wastes have on the marine environment; status and effectiveness of regulation and surveillance of present disposal operations. In addition, the panel was to recommend areas in which additional information and research are required. The results of discussions on present concepts, practices, and problems associated with marine disposal of the various classes of wastes are incorporated in the appropriate chapters of this report.

ACKNOWLEDGMENTS

In a national study of this type, it is not possible to acknowledge all the individuals, agencies, and organizations that provided information and assistance to the Dillingham staff during the course of this work. The following organizations were particularly cooperative: U.S. Army Corps of Engineers, U.S. Coast Guard, U.S. Navy, Federal Water Pollution Control Administration, Bureau of Sport Fisheries and Wildlife, Bureau of Commercial Fisheries, U.S. Public Health Service, National Oceanographic Data Center, U.S. Atomic Energy Commission, and the National Academy of Engineering. Many State and municipal organizations also participated. Robert C. Baxley of the legal firm Jones, Baxley, Crouch and McCarty of San Diego, was responsible for preparing the section on legal aspects (Appendix E).

In addition to the above, the writers acknowledge the following individuals for their cooperation or participation and for the information they supplied so willingly during the course of the study: Jack Balsamo, Charles Bulla, Leonard Burtman, David Clark, John Clark, Dr. William D. Clarke, Clarence C. Clemmons, Fred H. Dierker, Alfred Fernandes, F. H. Freiherr, Richard Grigg, Dr. M. Grant Gross, Charles G. Gunnerson, J. E. Hollis, Dr. Edward R. Ibert, LCDR Charles W. Koburger, Jr., Dr. Alan Longhurst, Dr. Robert H. Meade, John Merrell, M. Miskimen, Dennis O'Leary, Dr. Jack Pearce, Capt. Walter Putnam, W. E. Reece, Alan H. Rice, J. H. Rook, E. H. Shenton, Harvey F. Soule, Dr. Jerome E. Stein, Dr. Lyle St. Amant, Frank C. Small, Richard Stone, Charles Turner, Dr. Lionel A. Walford, and Robert H. Wuestefeld. The Solid Waste Management Office of the U.S. Environmental Protection Agency wishes to thank Capt. James L. Verber, Food and Drug Administration, Public Health Service, U.S. Department of Health, Education, and Welfare, for his careful review of, and certain revisions to, the manuscript and his compilation of Appendix B.

II. CURRENT MARINE DISPOSAL OPERATIONS

The major objective of this investigation was to inventory major classes of wastes being barged to sea. These findings were summarized in topical discussions of a description of the various major types of waste, a summary of the principal offshore disposal sites; a discussion of disposal methods, amounts, and costs.

DESCRIPTION OF WASTES

Wastes currently being transported aboard barges and ships for disposal at sea from the U.S. coastal cities surveyed have been summarized into seven major categories and ranked according to total volume: (1) dredge spoil, (2) industrial wastes, (3) sewage sludge, (4) refuse, (5) radioactive wastes, (6) construction and demolition debris, (7) military explosives and chemical wastes, and (8) miscellaneous.

For detailed information regarding the characteristics and problems associated with the disposal of these wastes, the reader should consult the following references: American Petroleum Institute, Revelle and Co-Workers, Tarzwell, Moss, U.S. Department of Agriculture, U.S. Coast Guard, Kurak, Sax, California State Department Public Health, Burd, and Sittig, National Academy of Sciences, and American Burd, and Sittig, National Academy of Sciences, and American Chemical Society.[1-15]

Dredge Spoil

Dredge spoil consists of sediments containing various concentrations of alluvial sand, silt, clay, and municipal or industrial waste sludges dredged to improve and maintain navigation channels. It is these sludges which put the Corps of Engineers into the municipal and industrial waste disposal business, giving the Corps a responsibility neither within its charter nor desired by that agency. Most of the dredging operations are conducted by the Corps with seagoing hopper dredges. These spoils are normally disposed of in open coastal waters generally not more than three to four miles from the dredging site.

Industrial Wastes

Industrial wastes originate from a variety of manufacturing and processing operations including petroleum refining, steel and paper production, pigment processing, insecticide-herbicide-fungicide manufacturing, chemical manufacturing, oil-well drilling operations, and metal finishing, cleaning, and plating processes, as well as many others. A brief description of several types of industrial wastes currently being disposed of at sea follows.

Refinery Wastes. Wastes from petroleum refining operations are produced during the chemical refining processing used to extract various products from the crude oil. These include spent caustic solutions, sulfuric acid sludges, dilute process water solutions, spent catalysts, petrochemical wastes, and chemical cleaning wastes. In many cases solid wastes, such as spent clay, catalysts, and sludges are slurried with liquid chemical wastes for disposal at sea.[1-3] The spent caustics and acid sludges also contain varying amounts of contaminants including: sulfides, sulfates, phenolates, napthenates, sulfonates, cyanides, heavy metals, mercaptides, chlorinated or brominated hydrocarbons, and other organic and inorganic compounds.

Spent Acids. Large quantities of spent sulfuric acid and ferrous sulfate are produced by steel mills. The acid, or "pickle liquor," is usually withdrawn from the operation and disposed of when one-half or two-thirds of the acid is converted to ferrous sulfate. Typical wastes contain up to 7 percent free acid and up to 30 percent ferrous sulfate. In recent years some steel mills have converted a portion of their pickling operations to hydrochloric acid which has resulted in reduced volumes containing spent hydrochloric and sulfuric acids.

Another major waste results from titanium pigment manufacturing in which the ore, with iron as a principle impurity, is digested with sulfuric acid. The wastes include the liquor with 7 to 9 percent free sulfuric acid and 8 to 10 percent ferrous sulfate and a mud slurry with 15 to 20 percent inert solids.

Pulp and Paper Mill Wastes. Pulp and paper mill wastes include the organic constituents of wood being pulped, dissolved salts from the digestion process, undigested pulp, and fibers that escaped processing. Depending on the process, the wastes may contain a sulfate cooking solution (calcium, magnesium or ammonia), "black liquor" (sodium hydroxide, sulfide, sulfate) and organic constituents including lignin, hexose and pentose sugars.

Chemical Wastes. Chemical manufacturing, chemical laboratories, metal cleaning finishing and electroplating processes, and a variety of other industrial operations all produce a host of complex waste chemicals. These include murcuric or arsenical compounds, organic acids, pesticide chlorinated hydrocarbons, alkalaes, anilines, cyanides, and other highly toxic substances. Chemical industry wastes are particularly complex in their composition and behavior.

Oil Drilling Wastes. Oil-well drilling wastes disposed of at sea consist primarily of drilling muds containing barite and diatomaceous clays and cuttings (rock chips) from the drill hole. This type of waste is physically similar to dredging spoils.

Waste Oil. These wastes consist principally of oil sludge that remains after any re-refining process. In the case of oil tankers, the wastes are oil residues resulting from tank cleaning operations (butterworthing). Sources of waste oil are numerous, diverse, and include service stations, ship tanks, tank cars, etc. At present, the Oil Pollution Control Act of 1961 restricts the disposal of these wastes at sea to areas beyond the 50-mile limit.

Sewage Sludge. Total solids in sewage include large and small suspended particles as well as matter in true solution. The weight of these solids is usually 0.03 percent or less of the total sewage solution by weight. Solids are removed and treated by screening, grit removal, primary sedimentation, final sedimentation, anaerobic digestion and thickening. Thickened sludges currently being disposed of at sea from barges generally range between 3 to 5 percent solids by weight.

Refuse

The survey revealed that only limited disposal of refuse and garbage at sea occurs. These wastes originate primarily from canneries and from commercial and naval vessels. Cannery wastes consist of ground fruit pits, skins, etc., and are disposed of on a seasonal basis. The composition of vessel refuse depends on the type of vessel, geographic location, and season, and consists of varying amounts of food, paper, plastics, metal, glass, and similar wastes.

Radioactive Wastes

The nuclear energy industry produces high activity, intermediate activity, low activity, and so-called nonactive wastes. Activities range from hundreds of thousands of curies per gallon for high activity wastes to microcuries per gallon for low activity wastes. Solid wastes include contaminated laboratory or process equipment, clothing, and other items. Between 1946 and 1967 the U.S. Atomic Energy Commission (AEC) disposed of limited quantities of solid packaged radioactive waste materials at designated disposal sites in the Atlantic and Pacific Oceans. In most cases these wastes were packaged in weighted 55-gallon drums. Most of these wastes are now disposed of on land. Nuclear vessels regularly discharge low-level liquid coolant wastes at sea under strict AEC regulations.

Construction and Demolition Debris

Typically, these wastes consist of masonary, tile, stone, plastic, wiring, piping, wood, and excavation dirt. At the present time, the only sea disposal of this type of waste is from New York City.

Military Explosives and Chemical Warfare Agents

This category includes unserviceable or obsolete ammunition such as shells, mines, solid rocket fuels, propellents, agents. Until 1964, the disposal of explosives was conducted primarily from barges and ships. Since then, gutted World War II Liberty ships have been utilized, being sunk with the wastes aboard in water depths greater than 6,000 feet.

Miscellaneous

Included in this category are various types of rejected or contaminated products, such as foodstuffs, appliances, small batches of toxic wastes (usually barreled) such as pesticides and complex chemical solutions. Wastes in this category are usually disposed of in small lots, and records regarding their disposal are difficult to obtain as the disposal operations are not often sanctioned by any regulatory agency.

Location of Disposal Areas

During the Dillingham study, 281 ocean areas designated for the disposal of wastes were identified. Data on locations and characteristics of these sites for Pacific, Atlantic and Gulf coastal waters were identified (Appendix B) when the regional distribution of disposal areas for the principal waste categories was summarized (Table 1).

TABLE 1
NUMBER OF MARINE WASTE DISPOSAL AREAS
(BY REGION AND WASTE TYPE)*

Waste type	Disposal areas			
	Pacific	Atlantic	Gulf	Total
Dredge spoil	15	83†	63	161
Industrial waste	9†	15†	16	40
Sewage sludge	0	2	0	2
Refuse	3†	0	0	3
Radioactive waste	10†	25†	2	37
Explosive and chemical ammunition	19†	19†	11	49
TOTAL (no duplicates)	54	135	92	281

* Revised and updated by James L. Verber, Food and Drug Administration, U.S. Department of Health, Education, and Welfare. (See Appendix B.)

† Areas used for two or more types of wastes.

It was evident that the number of disposal sites for dredge, spoil, industrial wastes, and explosives was not equal for the three coastal areas (Table 1) (Figures 1-3). Most radioactive waste disposal sites are located off the Atlantic Coast. Disposal sites for refuse were found on the Pacific Coast and those for sewage sludge, only on the Atlantic Coast. The Atlantic Coast has 48 percent of all disposal sites. Differences of location, shown in Appendix B, are the result of specific locations of some wastes, whereas other sites are shown as center points of large dump areas.

Sixty percent of the dredge spoil areas are located within 3 miles of the coast in water depths less than 100 feet. Most, but not all, of the radioactive and explosive waste disposal areas are situated at depths of 6,000 feet or more. Ocean depths of this magnitude are located 10 or more miles from the Pacific coast and 100 or more miles from the Atlantic and Gulf coasts. The explosive disposal areas are identified on U.S. Coast and Geodetic Survey charts, and in some cases these also serve as disposal areas for toxic industrial waste material.

Industrial and municipal waste disposal areas are situated at distances from 15 to 100 miles offshore depending on the type of waste and established regulatory procedures. For example, acid wastes are disposed of in a designated area 15 miles from the coast of New York City; by contrast, the disposal site for certain toxic chemical wastes is nearly 125 miles offshore. Most industrial waste disposal operations in the Gulf of Mexico are conducted beyond the 400-fathom line (2,400 feet), which off Galveston requires disposal about 125 miles off the coast.

Selection of Disposal Areas

Results of the present study show that past determinations of whether or not a given offshore area was suitable for waste disposal have been based primarily on the following considerations: (1) the disposal area should be far enough away from the coast and/or have an ocean depth deep enough to ensure that no identifiable wastes return to public beaches or interfere with fishing or recreation in coastal areas; (2) the disposal areas should be within a reasonable distance from the coast so that the costs of tug and barge operations are minimized.

In a small number of cases, the potential harm to the environment and the restrictions that the waste disposal operations might place on future exploitation of natural resources (i.e., fishing, minerals, oil research) were taken into consideration. Some studies have been conducted of various environmental aspects of individual disposal operations; these, however, have been limited in both scope and duration and in most cases were conducted after the disposal operations were in progress.

Disposal Methods and Costs

Methods employed for sea disposal of the various wastes consist primarily of transporting the wastes in bulk or containers aboard towed or self-propelled barges. Dredge spoil is handled routinely by U.S. Corps of Engineers aboard their oceangoing hopper dredges. Bulk wastes are normally discharged from tank barges while underway. Containerized wastes might, depending on local practices, be weighted and sunk, or ruptured at the sea surface by axes or rifle fire and allowed to sink. In a few cases highly toxic chemical wastes such as arsenic and cyanide are carried to sea regularly as deck cargo on merchant ships. The containers are then discharged overboard in undetermined areas once the ship is at least 300 miles from shore. In addition, an accepted method of disposal of spent caustics from oil refineries is as ballast on outgoing crude oil tankers that is discharged far at sea.[3]

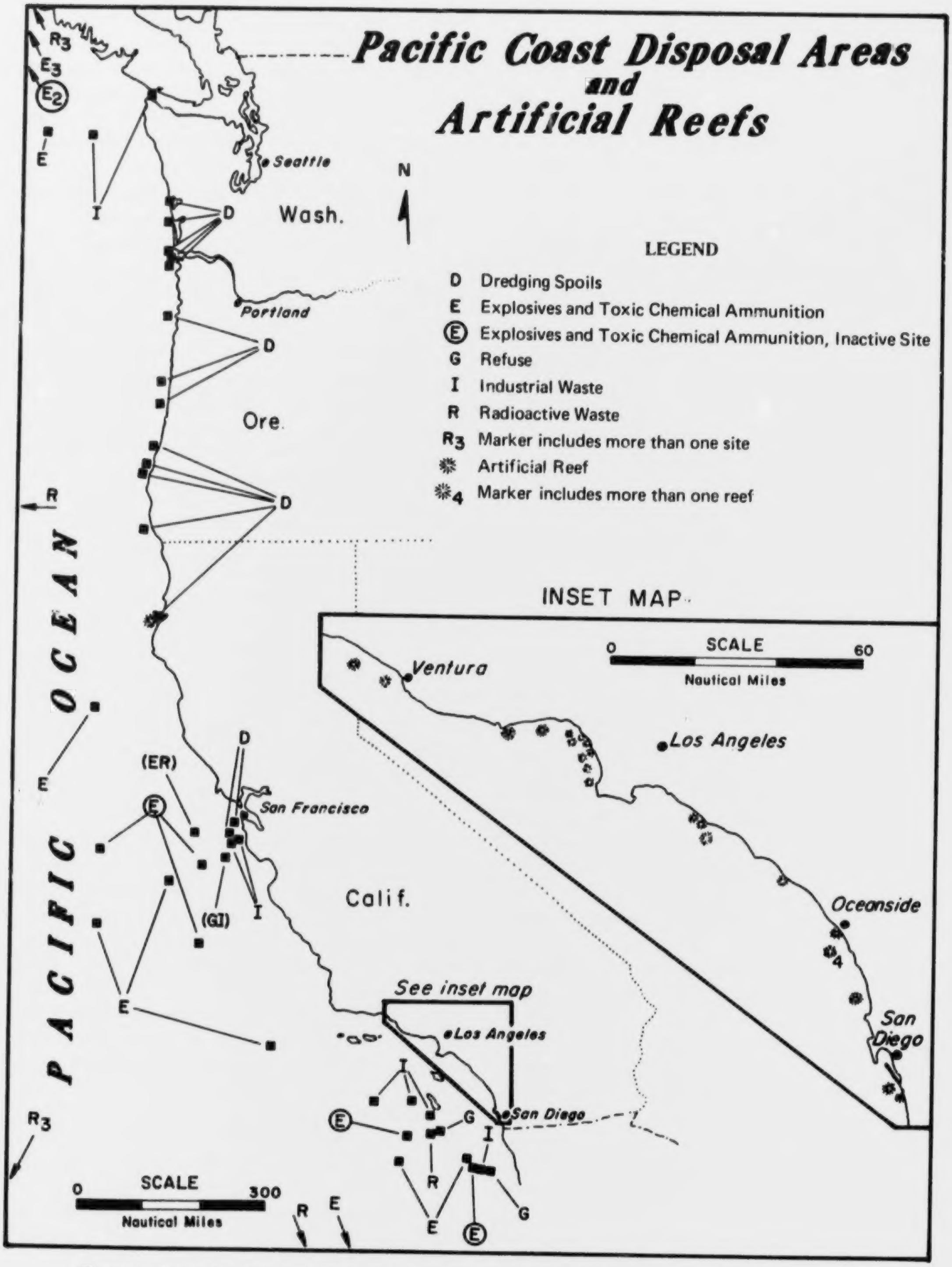
Pacific Coast Disposal Areas and Artificial Reefs
LEGEND
D Dredging Spoils
E Explosives and Toxic Chemical Ammunition
Ⓔ Explosives and Toxic Chemical Ammunition, Inactive Site
G Refuse
I Industrial Waste
R Radioactive Waste
R3 Marker includes more than one site
Artificial Reef
4 Marker includes more than one reef
N
Seattle
Wash.
Portland
Ore.
Calif.
San Francisco
Los Angeles
San Diego
See inset map
PACIFIC OCEAN
SCALE
0
300
Nautical Miles
INSET MAP
SCALE
0
60
Nautical Miles
Ventura
Los Angeles
Oceanside
San Diego
R3
E3
E2
E
I
D
R
(ER)
(GI)
G
4

Figure 1. The Pacific Coast was the only U.S. coast where authorized refuse disposal sites were found.

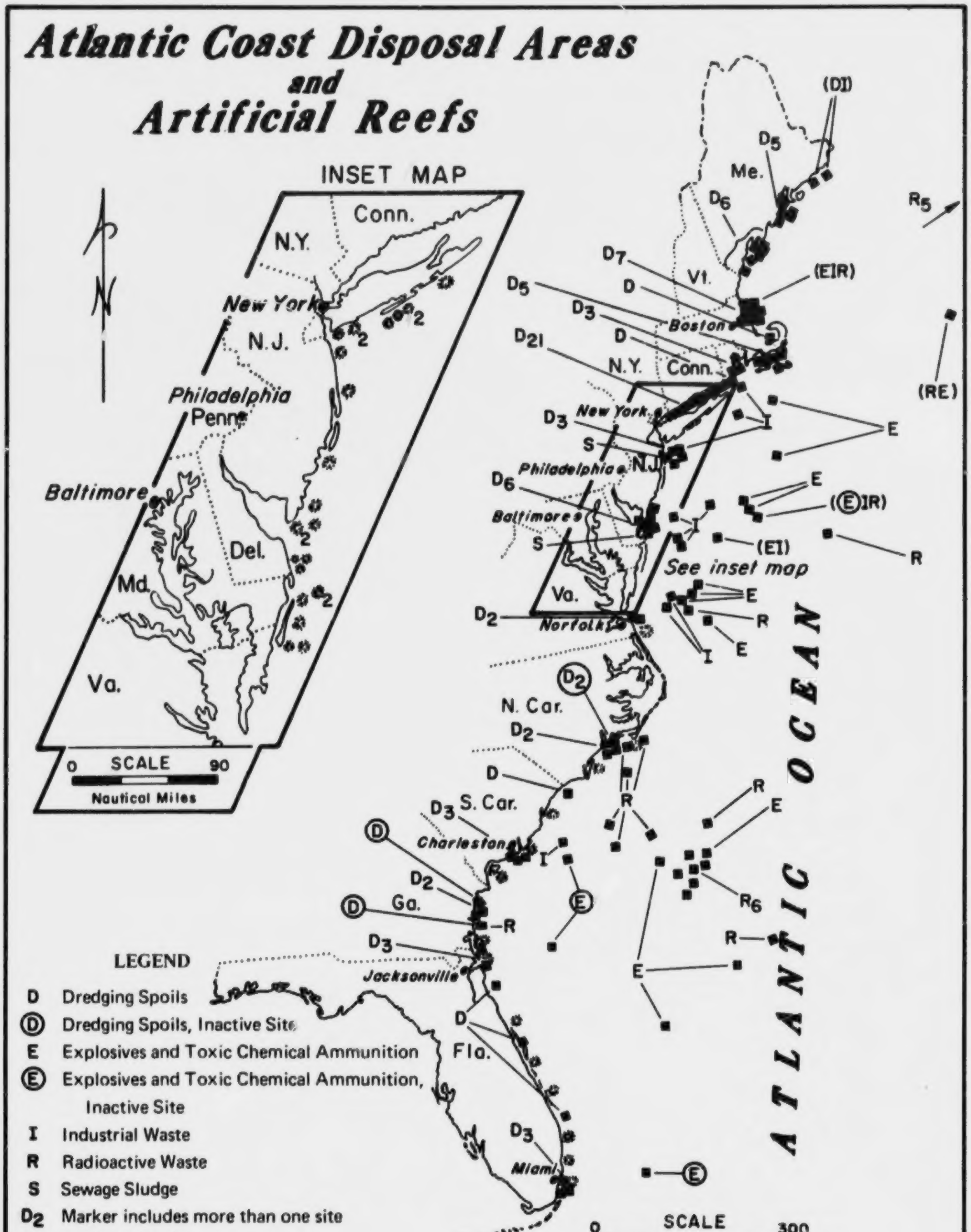
Atlantic Coast Disposal Areas and Artificial Reefs
INSET MAP
N.Y.
Conn.
New York
N.J.
Philadelphia
Penn.
Baltimore
Del.
Md.
Va.
0 SCALE 90
Nautical Miles
Me.
Vt.
Boston
N.Y.
Conn.
New York
Philadelphia
N.J.
Baltimore
Va.
Norfolk
N. Car.
S. Car.
Charleston
Ga.
Jacksonville
Fla.
Miami
See inset map
ATLANTIC OCEAN
(DI)
(EIR)
(RE)
(E)IR)
(EI)
0 SCALE 300
Nautical Miles
LEGEND
D Dredging Spoils
Ⓓ Dredging Spoils, Inactive Site
E Explosives and Toxic Chemical Ammunition
Ⓔ Explosives and Toxic Chemical Ammunition, Inactive Site
I Industrial Waste
R Radioactive Waste
S Sewage Sludge
D2 Marker includes more than one site
✱ Artificial Reef
✱2 Marker includes more than one reef

Figure 2. Sewage sludge disposal sites were only found on the Atlantic Coast, where most radioactive waste disposal sites were also located.

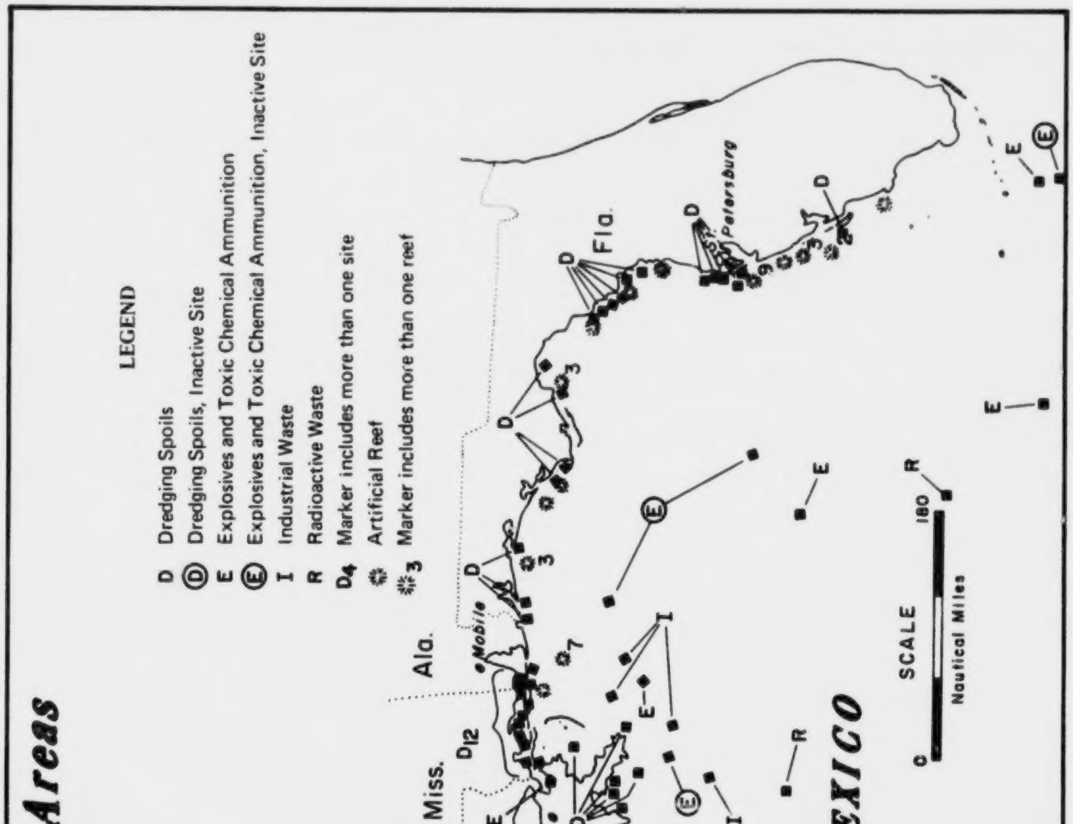
Gulf of Mexico Disposal Areas and Artificial Reefs
LEGEND
D Dredging Spoils
Ⓓ Dredging Spoils, Inactive Site
E Explosives and Toxic Chemical Ammunition
Ⓔ Explosives and Toxic Chemical Ammunition, Inactive Site
I Industrial Waste
R Radioactive Waste
D4 Marker includes more than one site
✹ Artificial Reef
✹3 Marker includes more than one reef
N
Texas
La.
Miss.
Ala.
Fla.
Houston
Port Arthur
New Orleans
Mobile
St. Petersburg
GULF of MEXICO
SCALE
0
180
Nautical Miles
D12
D6
D5
D4
I4
7
3
9

Figure 3. Most industrial waste disposal operations in the Gulf of Mexico are conducted beyond the 400-fathom line (2,400 feet), which off Galveston requires disposal about 125 miles off the coast.

Dredge Spoil

Corps of Engineers hopper dredges resemble small tankers in general appearance except for a large amount of deck equipment (Figure 4). The Corps presently owns and operates a fleet of 15 hopper dredges in U.S. coastal and inland waterways. Hopper dredges load by sucking up the bottom sediments through drags, or underwater pipes, while underway in the dredging area. In general, the hauling distance to the spoil disposal areas averages 3 to 4 miles, although in the New York area the trip to the designated offshore disposal area is more than 30 miles. An excellent description of hopper dredge disposal techniques has been presented by Mauriello and Caccese along with detailed information on the vessels and equipment used.[16] The 1968 costs per ton for dredge spoil disposal, ranged from 20 to 55 cents per ton, representing the reported total cost of the dredging operations and converting cubic yards to tons by utilizing a factor of 1.2 tons per cubic yard for average sediments consisting of a mixture of sand, silt, and clay (Table 2). Tonnages were generally based on average annual discharges, reflecting the years 1967 through 1969.

Industrial Wastes

Bulk industrial wastes are most commonly transported to sea in tank barges ranging in capacity from 1,000 to 5,000 short tons (Figures 5 and 6). These barges must be of double-skinned bottom construction and certified for ocean waters by the U.S. Coast Guard, which also promulgates regulations regarding the bulk shipment of chemicals by water.[8] The recently built $850,000 five-thousand capacity barge, *Sparkling Waters* was designed to handle insecticides and other toxic chemical wastes and operates out of New York (Figure 5).[17] *Sparkling Waters* reportedly can be emptied in 30 minutes. Discharge rates of conventional waste disposal barges vary between 4

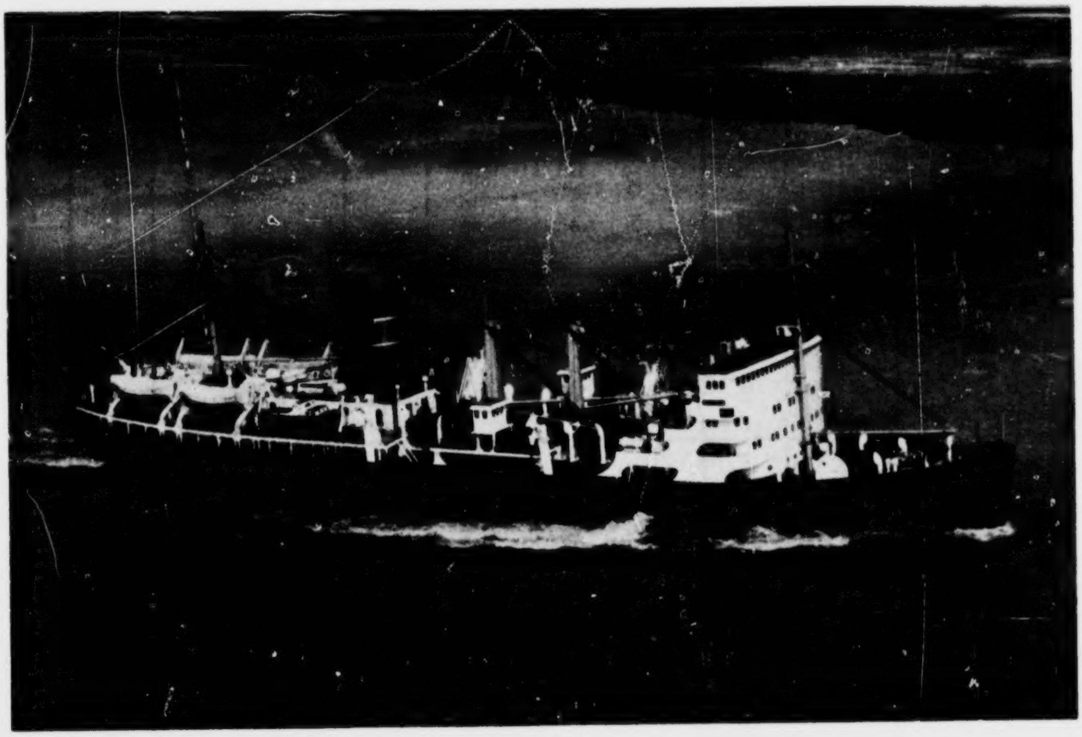

FIGURE 4. Corps of Engineers, U.S. Army, New Orleans District–Seagoing Hopper Dredge *Langfitt* enroute to dredging site in Southwest Pass, Mississippi River. (New Orleans District Corps of Engineers Photo).

TABLE 2
AVERAGE AND REPORTED RANGE OF COSTS PER TON FOR MARINE DISPOSAL OF WASTES IN U.S. COASTAL WATERS
1968

Type of Waste	Total U. S.		Pacific Coast		Atlantic Coast		Gulf Coast	
	Average cost/ton	Reported Range $/ton	Average cost/ton	Reported Range $/ton	Average cost/ton	Reported Range $/ton	Average cost/ton	Reported Range $/ton
Dredging spoils	$0.40/ton	$.20 - .55	$0.43/ton	None	$0.54/ton	$.40 - .55	$0.25/ton	$0.20 -.25
Industrial wastes								
Bulk	$1.70/ton	$0.60-9.50	$1.00/ton	$0.60-9.50	$1.80/ton	$.60-7.00	$2.30/ton	$.75-3.50
Containerized	$24/ton	$5-130	$53/ton	$50 - $130	$7.73/ton	$5 - $17	$28/ton	$10 - $40
Refuse and Garbage	$15/ton	$5 - $60	$15/ton	$5-$60				
Sewage sludge	$1.00/ton	$.80 - 1.20			$1.00/ton	$.80-1.20		
Construction and demolition debris	$0.75/ton	$.70 - 1.35			$0.75/ton	$.70 -1.35		
Explosives	$15/ton	$15 - $90						
Miscellaneous	$15/ton	$5 - $600	$15/ton	$5 - $600				

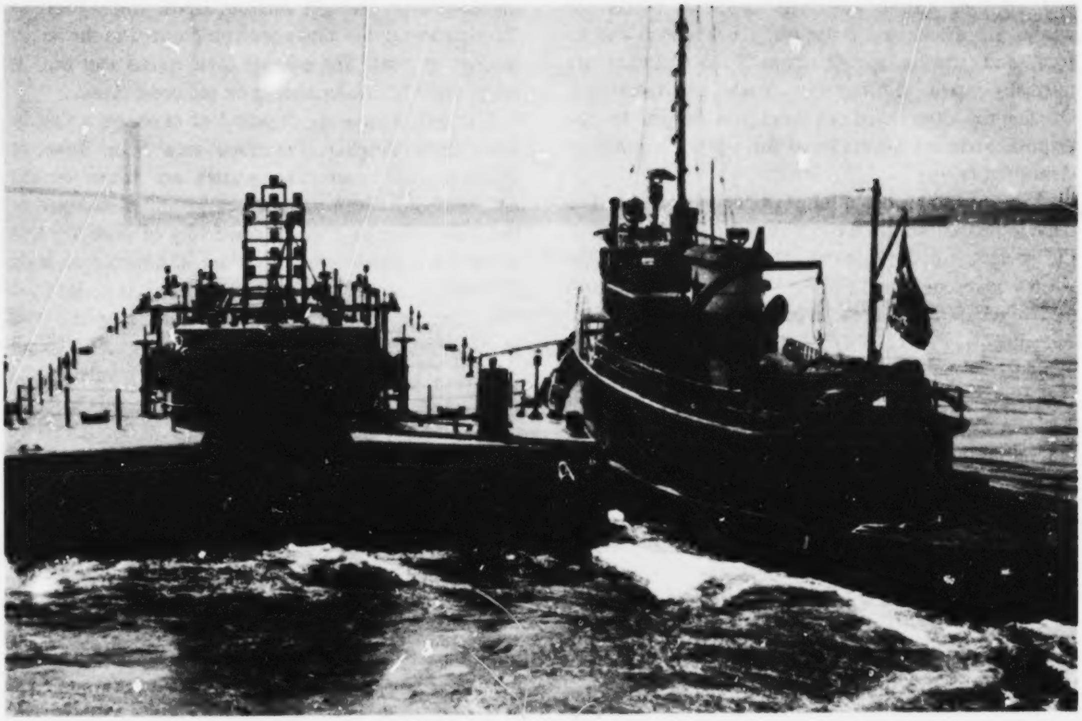

FIGURE 5. Automated chemical waste disposal barge, *Sparkling Waters,* under tow with a load of wastes for disposal beyond the Continental Shelf. (Photograph from Chemical Week.[17])

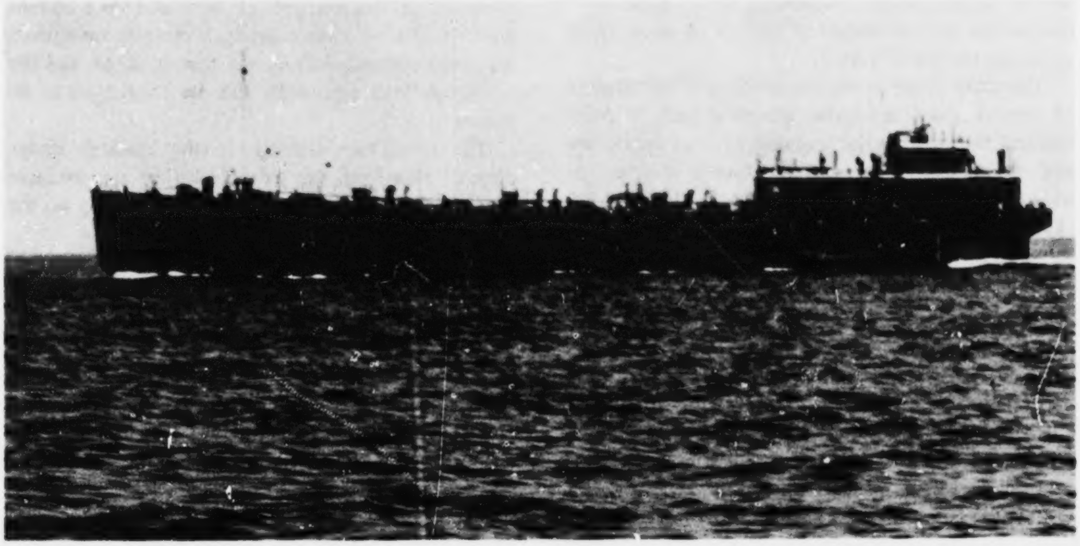

FIGURE 6. Acid disposal barge under tow off New York City (Photograph by Dr. J. Pearce, U.S. Bureau of Sport Fisheries and Wildlife).

and 20 tons per minute. The depth at which the wastes are discharged is typically between 6 and 15 feet, and towing speeds from 3 to 6 knots are normally used during the discharge operations. Oceangoing tugs used to haul the barges to the disposal areas are generally of the 1,000- to 2,000-hp class (Figure 6).

Average and reported range of costs for disposal of bulk industrial wastes were computed on the basis of the weight of the volume of water in which the wastes were contained (Table 2). Costs varied according to geographical area, type of waste, distance to the disposal area, and annual volume of wastes handled. Disposal costs estimated by the Dillingham Corporation for industrial wastes (Table 2) represent a synthesis of the data supplied from three sources: (1) published, (2) waste producers, and (3) barging firms. These figures represent actual barging costs and do not include other costs incurred by the waste producers for treatment, storage, loading, etc., of the wastes. Although attempts were made to verify the "ball park estimates" supplied by interviewees, when discrepancies between the three sources could not be reconciled, costs reported by the waste producer were used.

Toxic industrial liquids and sludges are also disposed of at sea in containers, usually 55-gallon drums, either routinely or on demand. These wastes are transported to sea as deck cargo on either merchant ships or contract disposal vessels. Once at sea, the barrels are jettisoned. Depending on local practices the barrels may be weighted for sinking or ruptured at the sea surface (Figure 7).

The wide range in the reported costs for disposal of containerized industrial wastes reflects the differences between regular ongoing disposal operations and those where occasional disposal of toxic or hazardous wastes is required by a waste producer (Table 2).

Refuse and Garbage

Refuse and garbage originating from naval and commercial vessels are transported to sea in various versions of the U.S. Navy's YG class scows (Figure 8). Load capacity varies between 25 and 136 tons.[19] About one trip per week of a 136 ton scow is the average for these disposal operations at San Diego, California. Disposal areas are located at least 20 miles from the coast as prescribed by California law. Once at sea, flood gates are opened, and the refuse is discharged on the sea surface. Upon completion of the unloading, the tanks are hosed out, and the vessel returns to port. The average total round trip time is six to eight hours depending on sea conditions.

Cannery wastes are disposed of at sea on a weekly basis from the San Francisco area from June to October each year. The wastes are taken to sea aboard a 1,000-ton capacity barge and discharged at the sea-surface as a slurry consisting of seawater and wastes. Discharge operations are conducted at least 20 miles from the coast while the barge is under tow. The average costs for the disposal of refuse and garbage are about twice the figure usually found quoted for various proposed schemes involving the disposal of municipal wastes at sea (Table 2).[19]

Sewage Sludge

About one half of the total tonnage of sewage sludge disposed of at sea from the New York area is handled by a fleet of five self-propelled barges operated by the city of New York at a reported annual cost of $1.25 million (Figure 9). These barges have capacities of between 1,200 and 3,200 tons.

In addition, contract firms regularly transport sludge to sea from various outlying communities in the New York-New Jersey area. Equipment owned by these independent firms ranges from 3,000 to 6,300 tons capacity. The largest is the *Ocean Disposal No. 1* which is 226 feet long, 56 feet wide and has a 20-foot draft.[21] The unloading and tank cleaning operations are radio controlled from the towing barge, and the 6,300-ton load reportedly can be discharged in 30 minutes.

The round-trip distance to the offshore sludge disposal area from the New York City area averages about 30 miles, although it varies depending on the location of a particular treatment plant.

In contrast to the large-scale sludge disposal operations from New York City, sewage sludge from Philadelphia is handled by a single converted tank barge having a capacity of 2,700 tons.[22,23] Total annual cost of this barging is $336,000. About 150 trips a year are made to the disposal area situated about 10 miles off Cape May, New Jersey. The round-trip barge-haul to this area is 227 miles and takes about 30 hours.

Average and reported ranges of costs for sludge disposal at sea reflect the variations in hauling distances, annual amount of wastes handled by

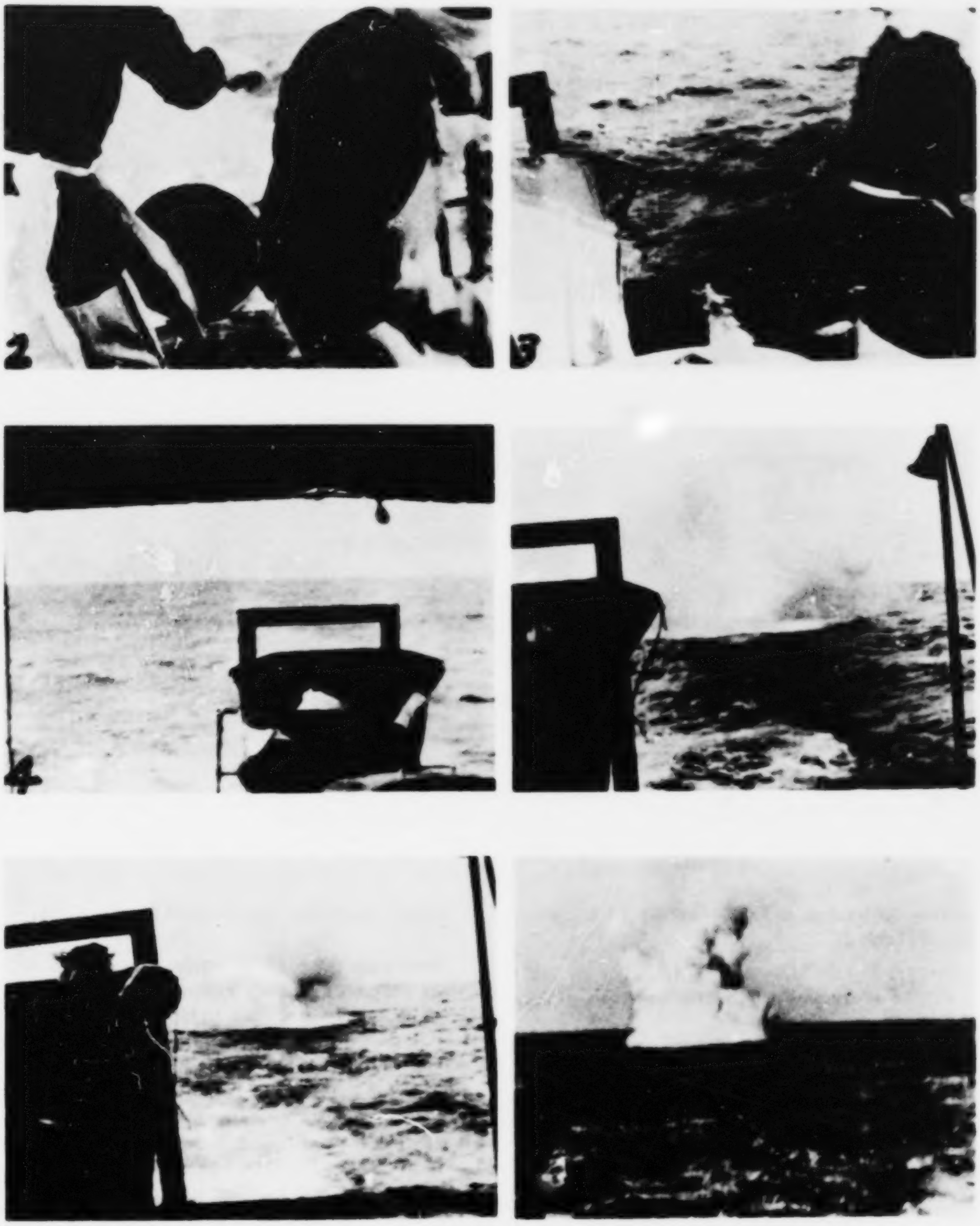

FIGURE 7. Photographic sequence showing the disposal of barreled sodium sludge at sea in the Gulf of Mexico. Note the protective clothing and use of the screen. (From Stein, JE.[18])

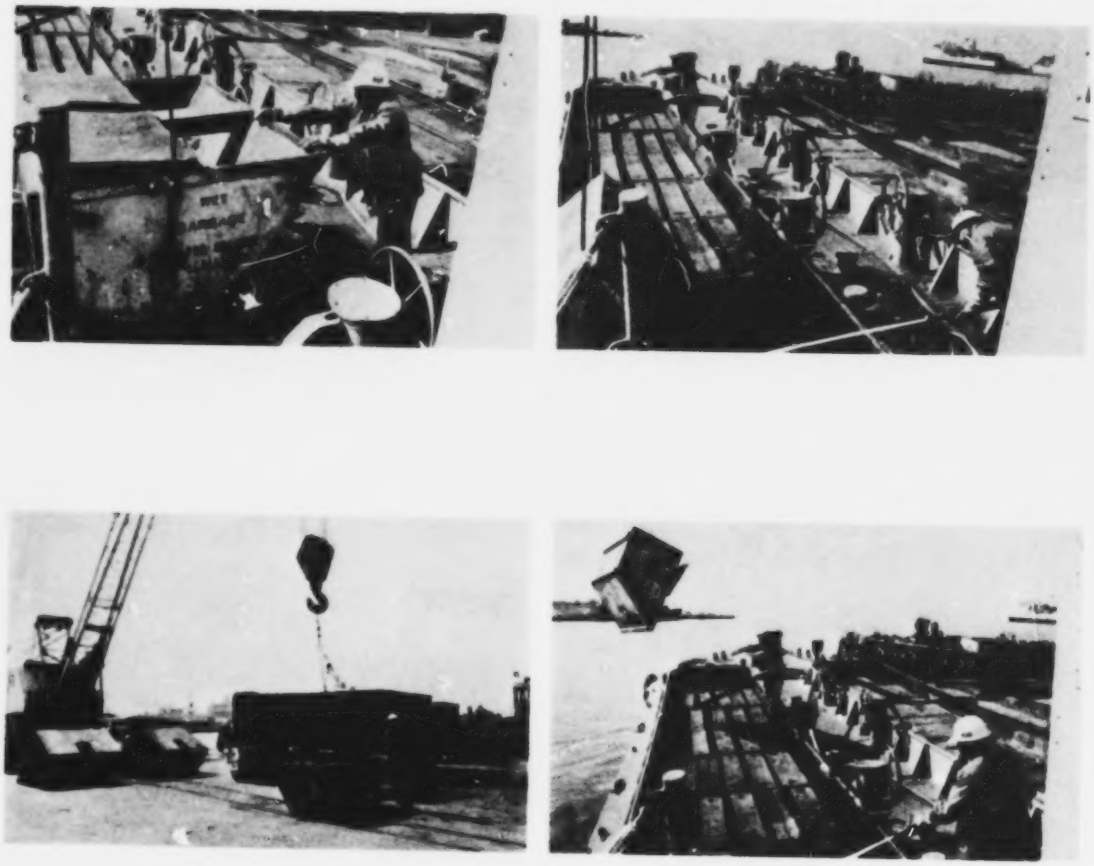

FIGURE 8. Loading garbage aboard a U.S. Navy Y-G scow for sea disposal. (Photograph from Marlin and Pomeroy.[19])

private contractors and the capacity of individual barges (Table 2).

Construction and Demolition Debris

Construction and demolition debris from the New York City area is disposed both in landfill and at sea. Sea disposal is conducted with 3,000 to 5,000-ton-capacity hopper barges (Figure 10) that are towed to the offshore disposal area situated nine miles seaward of the Sandy Hook Light or some 15 to 20 miles off New York City.

Costs for the disposal of these wastes is from $.70 to $1.35 per ton and averaging $.75 per ton (Table 2). Variations in cost are due to differences in quantities and the length of barge haul.

Military Explosives and Chemical Warfare Agents

Deep-water disposal of outdated munitions and other dangerous military explosives has been practiced for many years. Prior to 1964, the wastes were loaded aboard various types of barges and towed to sea for disposal. It has been estimated that it costs $78 per ton to dispose of explosives by this method.[9] The method was hazardous because of repeated handling of the wastes both onshore and at sea.

In 1963 the U.S. Navy conceived the idea of the CHASE (Cut Holes and Sink Em) disposal program. The inspiration for this method came from the U.S. Army, which in 1958 scuttled the obsolete World War II vessel, *S.S. Wm. Ralston*, with 8,000 tons of mustard and lewisite gas aboard.[9] The CHASE

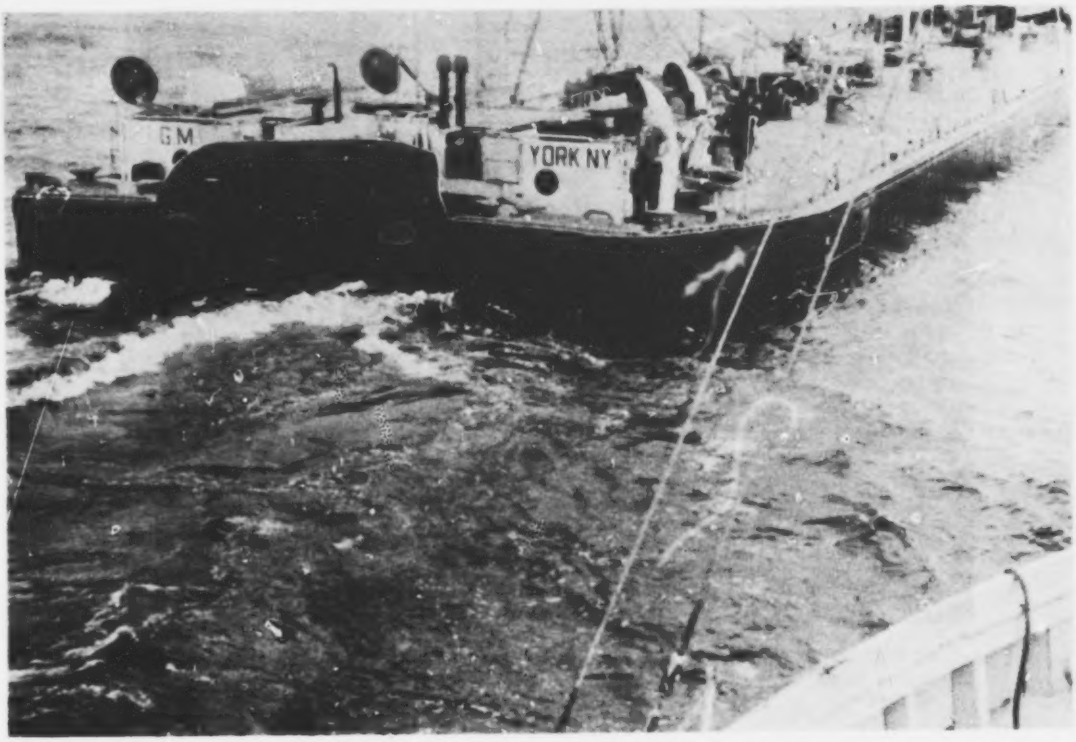

FIGURE 9. Sewage sludge disposal barge discharging its load in the New York Bight disposal area. (Photograph by Dr. J. Pearce, U.S. Bureau of Sport Fisheries and Wildlife).

program obtains obsolete, surplus World War II cargo ships (Figure 11), which are stripped of any useable equipment or machinery, filled with explosive wastes and towed to sea to be sunk by flooding in the designated deepwater disposal sites. Through 1968, 12 such disposal operations have been conducted.

These disposal operations have not been conducted without problems.[24] Two disposal ships have unexpectedly exploded upon contact with the sea floor. In addition, as part of the AEC's Vela Uniform seismic test series, the *S.S. Robert L. Stevenson,* loaded with 2,400 tons of explosives, was scuttled in 1967 in 4,000 feet of water off Amchitka, Alaska, with her cargo set for detonation at middepth. Instead of sinking as planned, she drifted and eventually sank in water shallower than that required to trigger the hydrostatic detonator. Although subsequent search located the vessel, attempts to detonate her cargo were fruitless.[24] The Navy terminated the operation on the basis that the detonation attempts indicated that the hulk was no longer a threat. Hydrographic notices and charts now inform interested mariners of the exact location of the *Stevenson.*

Cost figures are available for the disposal of explosive wastes for the CHASE operations, involving the *S.S. Mormactern* and *S.S. Richardson,* respectively, which were scuttled in the Atlantic Ocean during 1968 (Table 3). A detailed cost breakdown for the eleven CHASE disposal operations conducted from 1964 through 1968 is also available (Table 3).

Radioactive Wastes

The disposal of low-level radioactive wastes has utilized weighted containers carried to sea on the decks of barges or ships. The most common methods of packaging has been to encase the wastes in concrete contained in 55-gallon steel drums (Figure 12). Atomic Energy Commission regulations require a minimum weight of 550 pounds to ensure sinking.

Pressure tests on the various types of containers have been conducted in the past both in the laboratory and at sea to determine if the containers

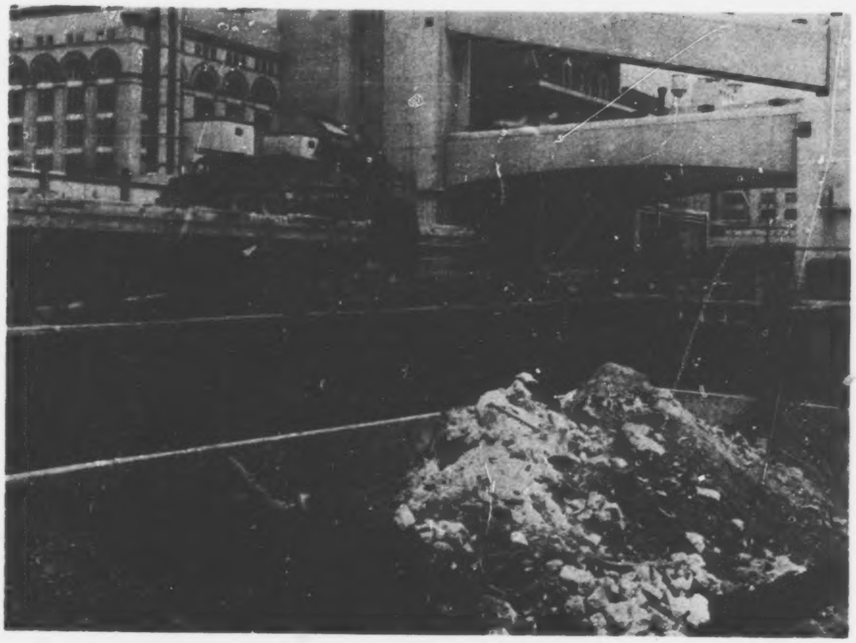

FIGURE 10. Construction and demolition debris from New York City being loaded aboard hopper barges for sea disposal. (Photograph courtesy of Jack Balsamo, Moran Towing Corporation).

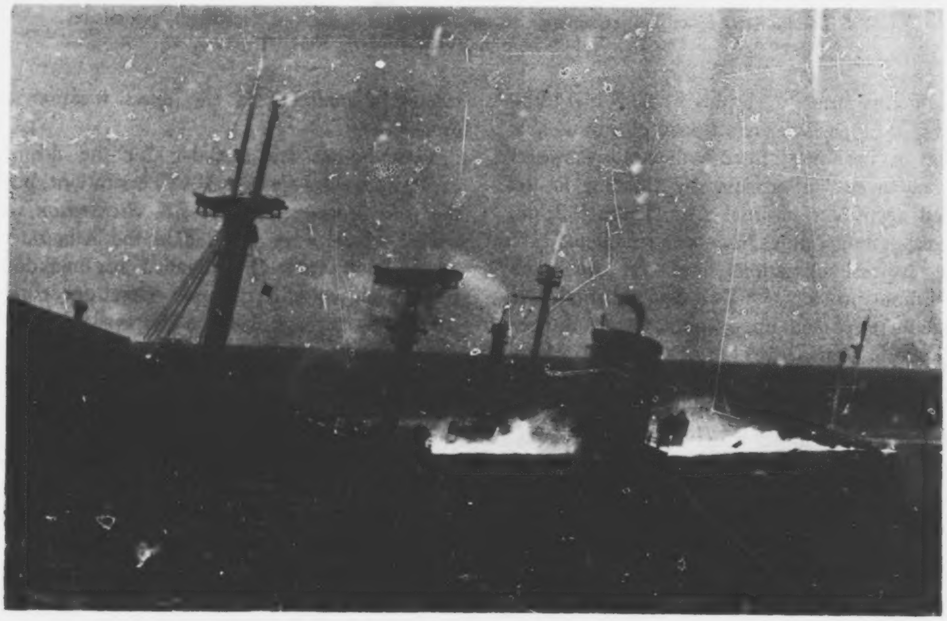

FIGURE 11 U.S. Navy CHASE vessel scuttled with a load of explosives in the Atlantic Ocean. (Official U.S. Navy Photograph. Source: Mr. A. Fernandes, Navy Ordnance Systems Command).

would rupture under increased water pressure as a result of air voids inside the container.[25-27] The results of these tests have shown that although physical deformation of the containers does occur, the containers maintain their integrity in containing the wastes (Figure 13).

Low-level radioactive wastes resulting from the operation of U.S. Navy nuclear submarines are regularly discharged at sea from the submarines themselves and from storage tanks aboard submarine repair ships. For example, the *U.S.S. Sperry* has three 15,000-gallon tanks for this purpose; the wastes in

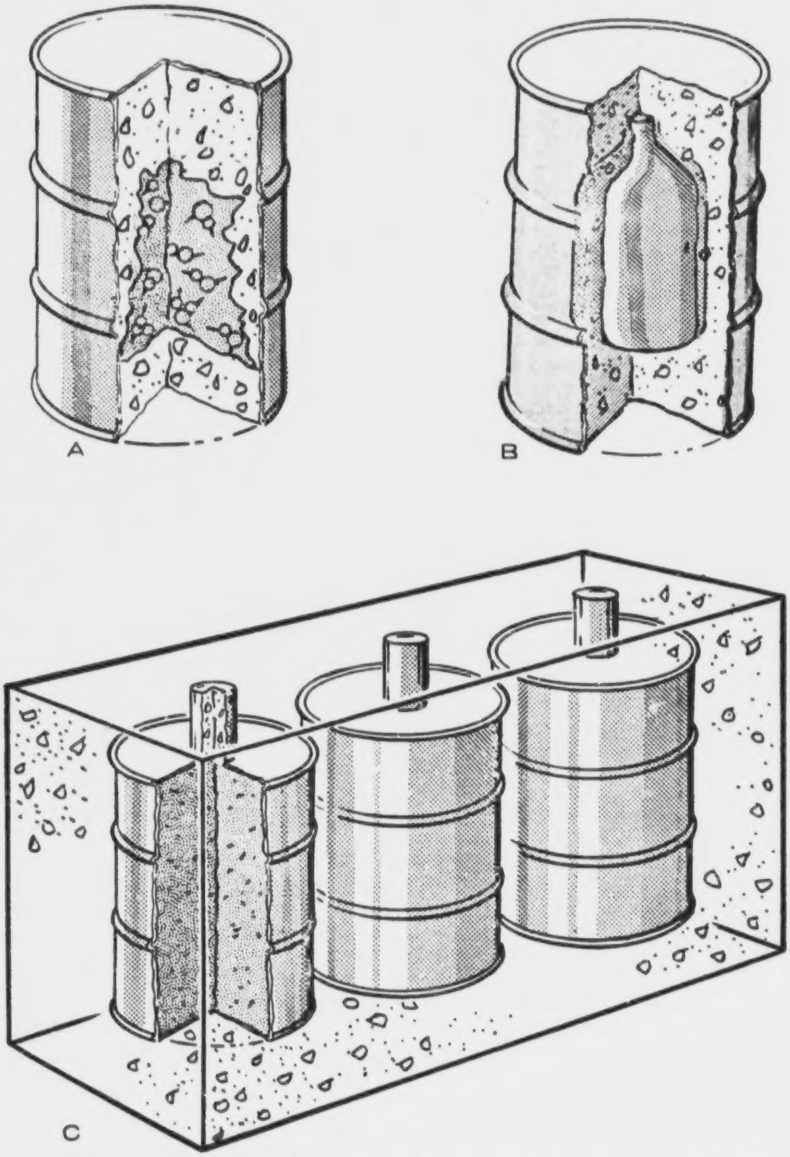

FIGURE 12. Methods used for packaging low-level radioactive wastes for sea disposal. A)–solid material, B) and C)–liquid wastes. (Source: Pneumo Dynamics Corporation.[25])

TABLE 3
SUMMARY OF U.S. NAVY CHASE DISPOSAL OPERATIONS, 1964–1968[a]

Chase Number	I	II	III	IV	V	VI
Year	1964	1964	1965	1965	1966	1967
Vessel Name	S.S. John F. Shafroth	S.S. Village	M.V. Coastal Mariner	S.S. Santiago Iglesias	S.S. Isaac Van Zandt	S.S. Robert L. Stevenson
Total Cargo	9,799 tons	7,535 tons	4,040 tons	8,715 tons	7,500 tons	6,600 tons
Net Explosive	Unknown	Unknown	512.19 tons	408 tons	1,625 tons	2,327 tons
Disposal Area	Pacific Coast Lat: 37° 40' N Long: 123° 25' W	Atlantic Coast Lat: 38° 49' N Long: 72° 14' W	Atlantic Coast Lat: 37° 12' N Long: 74° 21' W	Atlantic Coast Lat: 37° 11' N Long: 74° 26' W	Pacific Coast Lat: 39° 33' N Long: 125° 46W	Pacific Coast Lat: 51° 22' N Long: 178° 19'E
Hull Preparation Cost	$7,949	$3,608	$5,991	$2,235	$50,156	$64,354
Towing Cost[a]	$5,000	$1,000	$ 990	$1,075	0 (Navy Tug)	$39,000[b]
Loading Cost	$102,021	$158,235	$132,978	$178,112	91,859	$91,034
TOTAL COST	$114,970	$162,843	$139,959	$181,422	142,015	$155,388
Cost per ton of Total Waste Cargo	$12	$21	$34	$20	$19	$23

For Footnotes See End of Table.

TABLE 3–(Continued)
SUMMARY OF U.S. NAVY CHASE DISPOSAL OPERATIONS, 1964–1968[a]

Chase Number	VII	VIII	IX	X	XI	XII
Year	1966	1967	1967	-	1968	1968
Vessel Name	S.S. Hoarce Greeley	S.S. Corporal Eric G. Gibson	S.S. Monahan	re-scheduled for 1970	S.S. Mormactern	S.S. Richardson
Total Cargo	6,033 tons	9,004 tons	833 tons	-	7763 tons	7,437 tons
Net Explosive	442 tons	None	Unknown	-	Not Applicable	138 tons
Disposal Area	Atlantic Ocean Lat: 36° 34'N Long: 74° 16'W	Atlantic Ocean Lat: 39°37'N Long: 70°57'W	Atlantic Ocean Lat: 31°40'N Long: 75°56'W	-	Atlantic Oc. Lat: 39°38'N Long: 71°02'W	Atlantic Oc. Lat: 39° 33'N Long: 71°02'W
Hull Preparation Cost	$12,566	$32,390	$15,482	-	$31,953	$36,263
Towing Cost[c]	$1,000	$ 6,850	$ 15,000	-	$ 8,131	$ 6,802
Loading Cost	$90,050	$90,050	$ 46,000	-	$77,630	$74,435
TOTAL COST	$146,006	$129,290	$ 76,482	-	$117,714	$117,435
Cost per ton of Total Waste Cargo	$24	$14	$92	-	$15	$16

[a] Source: U.S. Navy Ordance Systems Command, Washington D.C.
[b] Tow distance was beyond designated Deep Water Disposal Site.
[c] Cost includes tow from reserve fleet to shipyard, to loading activity, to disposal site.

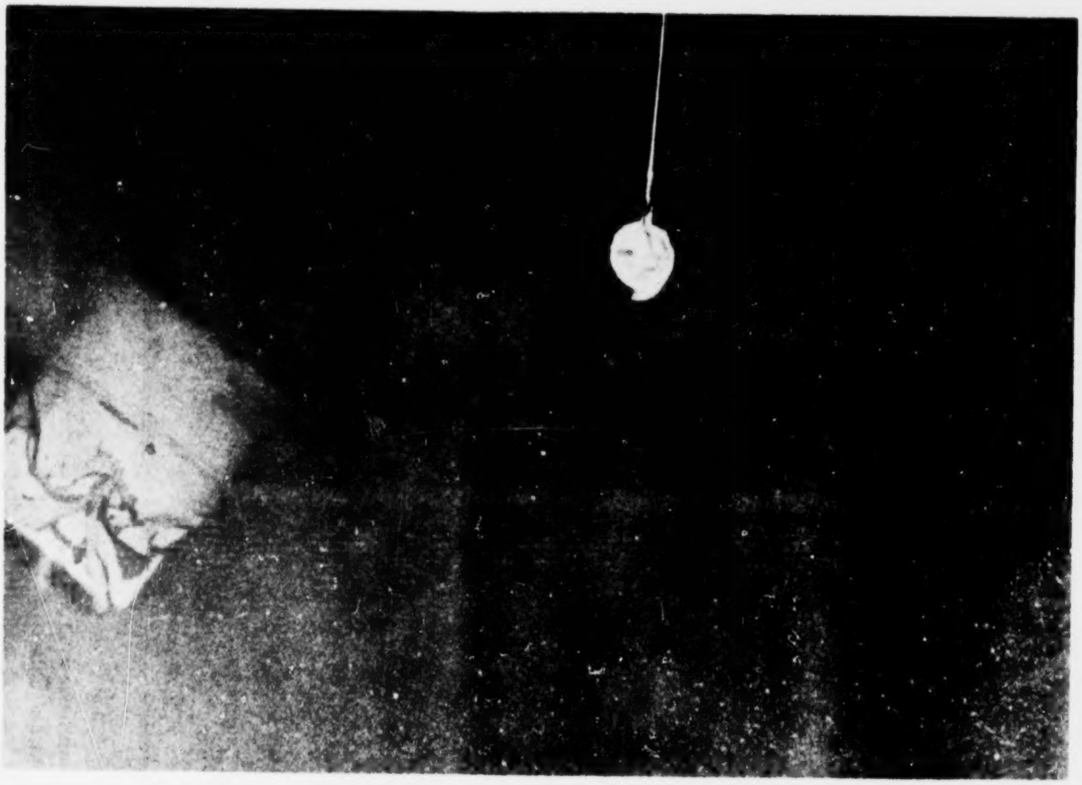

FIGURE 13. Partially crushed disposal drum resting on the bottom at a depth of 8,400 feet off the Farallon Islands, California. Object in center of the picture is a camera tripping device. (From Pneumo Dynamics Corporation.[24])

these tanks must be disposed of at sea in accordance with specific requirements such as depth and rate of pumping.[28]

Miscellaneous Wastes

Various types of wastes including barreled chemicals and sludges, defective industrial products, etc., are transported to sea on the decks of barges and ships. In some areas these wastes are "added" to a regular load of wastes whose disposal has been sanctioned by a regulatory agency. As might be expected, no records are kept regarding these operations. The costs to handle disposal of wastes in this manner are strictly based on individual cases. For example, it was noted during one interview that a lot of five barrels of highly toxic chemical sludge had been disposed of at sea along with a regular disposal load at a cost of $50 per barrel, equivalent to approximately $200 per ton wet weight.

TONNAGE OF CURRENT DISPOSAL OPERATIONS

During 1968 some 62 million tons of wastes from the civilian and military sector were disposed of at sea at an estimated cost of $37 million (Table 4). If dredging spoils are excluded, this estimate is reduced to 9.8 million tons disposed of at a cost of roughly $13.7 million. Excluding spoils, the tonnage from Atlantic coastal cities is more than eight times that from either the Pacific or Gulf coastal cities.

Dredge Spoil

Although dredge spoil is by far the largest of the waste categories being discharged at sea, it does not rank low on the scale with respect to producing adverse effects on the marine environment. Dredge spoil discharged at sea off the Pacific Coast is about one-quarter that disposed off the Atlantic and more

TABLE 4
SUMMARY OF TYPE, AMOUNT AND ESTIMATED COSTS OF WASTES DISPOSED OF IN PACIFIC, ATLANTIC, AND GULF COAST WATERS FOR THE YEAR 1968 *

Waste type	Pacific Coast		Atlantic Coast		Gulf Coast		Total		Total	
	Annual tonnage	Estimated cost$	Annual tonnage	Estimated cost $	Annual tonnage	Estimated cost $	Annual tonnage	Estimated cost $(e)	% Tonnage	% Cost
Dredging spoils	8,320,000	3,608,000	30,880,000(a)	16,810,000	13,000,000	3,228,000	52,200,000	23,646,000	84	63.5
Industrial wastes										
bulk	981,000	991,000	3,011,000	5,406,000	690,000	1,592,000	4,682,000	7,989,000	8	21.7
containerized	300	16,000	2,200	17,000	6,000	171,000	8,500	204,000	<1	<1
Refuse, garbage(b)	26,000	392,000					26,000	392,000	<1	1
Sewage sludge(c)			4,477,000	4,433,000			4,477,000	4,433,000	7	12
Miscellaneous	200	3,000					200	3,000	<1	<1
Construction and demolition debris			574,000	430,000			574,000	430,000	1	1
Explosives			15,200	235,000			15,200	235,000	<1	<1
Total, all wastes(d)	9,327,500	5,010,000	38,959,400	27,331,000	13,696,000	4,991,000	61,982,900	37,332,000	100	100

(a) Includes 200,000 tons of fly ash.
(b) At San Diego 4700 tons vessel garbage at $280,000 per year were discontinued in November 1968.
(c) Tonnage on wet basis. Assuming average 4.5 percent dry solids, this amounts to approximately 200,000 tons dry solids per year being barged to sea.
(d) Radioactive wastes omitted. There were no dumps during 1968. Average Annual disposal in 1969–1970 was 4.2 tons.
(e) Estimated costs were increased proportionately for each area from the original Tonnage/cost data.
* Revised and updated by James L. Verber, FDA.

than one-half off the Gulf Coasts. The reason for this is the practice in the State of California of returning sand and other sediments dredged from harbor entrances to the land for beach restoration or landfill operations. By estimates from the Corps of Engineers nearly 34 percent of the dredge spoils are polluted (Table 5).

TABLE 5

ESTIMATED POLLUTED DREDGE SPOILS*

Area	Total spoils (tons)	Estimated percent of total polluted spoils	Total polluted spoils (tons)
Altantic	30,880,000	45	13,896,000
Gulf	13,000,000	31	4,030,000
Pacific	8,320,000	19	1,580,800
Totals	52,200,000	34	19,506,800

* Source: Council on Environmental Quality. Ocean Dumping; A National Policy; a Report to the President. Washington, U.S. Government Printing Office, 1970. p. 3. Table revised and updated by James L. Verber, Food and Drug Administration.

Industrial Wastes

After dredge spoil, industrial waste tonnage and costs are the second largest waste category. The 4.7 million tons of bulk industrial wastes (10 percent of the total tonnage) discharged at a cost of nearly $8 million (27 percent of the total cost) by 50 separate industrial waste producers was distributed as follows:

	Percent of total industrial wastes	
Major Types of Industrial Waste	(Tons)	$
Waste acid	58	59
Refinery wastes	12	7
Pesticide wastes	7	15
Paper mill wastes	3	7
Others	20	12

Most of the pesticide wastes are from the Mississippi Valley, principally the Memphis area. An estimated 14,000 tons per month are loaded onto barges and shipped, not through New Orleans but via the intra-coastal canel to Beaumont. From here they are shipped to approximately 100 miles offshore and discharged into 200 fathoms of water.

In a similar vein, proposals have been made for barging down the Ohio and Mississippi Rivers and ocean disposal of industrial wastes originating in West Virginia. Digested and dried sewage sludge is being barged via the Mississippi and Gulf of Mexico to users in southeastern states. These events are significant because they demonstrate that marine disposal of wastes is, in the minds of authorities, within the reach of most major urban and industrial areas of the United States.

When coastal cities disposing of more than 12,000 tons of industrial waste per year at sea are ranked according to tonnage, New York's operations are more than four times as great as Los Angeles, and nearly one-third more than the total tonnage of the other eight areas considered.

	Industrial Waste (tons per year)
New York City	2,700,000
Los Angeles	660,000
Houston-Galveston-Beaumont, etc.	320,000
New Orleans	300,000
Philadelphia	290,000
San Francisco	200,000
Seattle	120,000
Norfolk	60,000
Mobile	12,000

Waste acid makes up over 90 percent of the total industrial wastes going to sea from New York City. In contrast, the bulk of the tonnage discharged from Los Angeles consists of sediment- like oil drilling muds and cuttings. Both of these have been considered to be relatively harmless in terms of environmental pollution.

Refuse and Garbage

The total volume of refuse and garbage currently being disposed of at sea is small (less than one percent of tonnage and cost) compared to most other wastes, and is confined to the Pacific coast. Major sources are from naval and commercial vessels and cannery operations.

Sewage Sludge

Sewage sludge from New York and Philadelphia ranks third in importance with 7 percent of the tonnage and 12 percent of cost. The total amount of sludge from the New York area is about ten times as great as that discharged by the city of Philadelphia. Both these operations are projected to increase significantly during the next ten years. In addition, the city of Baltimore is planning to dispose of some 400,000 tons of sewage sludge per year in 1970 in the disposal area now used by the city of Philadelphia.[29] The permit for this disposal is now pending and may be withheld.

Construction and Demolition Debris

The disposal of these wastes at sea occurs only from the city of New York and represents an alternate solution to offset the lack of available landfill. In 1968, 574,000 tons were disposed, however, yearly quantities of these wastes vary considerably in accord with construction operations.

Military Explosives and Chemical Wastes

The total tonnage of military explosives disposed at sea in 1968 represents the total cargo that was sunk during CHASE operations XI and XII (Table 4). The disposal of these wastes at sea is intermittent and depends on the backlog of outdated munitions that develops at individual military ordnance depots.

Radioactive Wastes

These wastes were not considered for 1968 since for all practical purposes the disposal of radioactive wastes at sea from the United States was almost nonexistent in that year. As a basis for comparison, however, the sea disposal of U.S. radioactive wastes from its inception in 1946 to 1967 (prepared from data supplied by the AEC) has been summarized (Table 6). The U.S. disposed of 3.6 tons of solid wastes in 1967 with a total activity of 61.8 curies. In contrast, barrelled radioactive wastes from member countries of the European Nuclear Energy Agency are still being disposed of at sea, so that in 1967, "some 11,000 tons of solid wastes with a total activity of approximately 8,000 curies were deposited at a depth of 5,000 meters in the eastern Atlantic Ocean."

TABLE 6

TOTAL U.S. SEA DISPOSAL OF RADIOACTIVE WASTES (1946 through 1967)*

Disposal area	Number of containers	Byproduct material (curies)	Source material (pounds)
Pacific Ocean	52,538	14,708	1,895
Atlantic Ocean	33,998	79,484	Unknown
Gulf of Mexico	1	10	Unknown
TOTALS	86,537	94,202	1,895

* Source: U.S. Atomic Energy Commission, Division of Operational Safety.

Miscellaneous Wastes

The data available for this type of waste are only crude approximations (Table 4). It is known with certainty that small volumes of wastes such as toxic chemical sludges, rejected industrial products, etc., are being disposed of at sea on a clandestine basis, but no clear picture as to tonnage or cost is available because of the nature of these operations.

REFERENCES

1. AMERICAN PETROLEUM INSTITUTE, DIVISION OF REFINING. Manual on disposal of refinery wastes. v. 3. Chemical wastes. New York, 1960. 93 p.
2. AMERICAN PETROLEUM INSTITUTE, DIVISION OF REFINING. Manual on disposal of refinery wastes. v. 6. Solid wastes. New York, 1963. 51 p.
3. AMERICAN PETROLEUM INSTITUTE, DIVISION OF REFINING. Manual on disposal of refinery wastes. Volume on liquid wastes. New York, 1969.
4. NATIONAL ACADEMY OF SCIENCES COMMITTEE ON EFFECTS OF ATOMIC RADIATION ON OCEANOGRAPHY AND FISHERIES. The effects of atomic radiation on oceanography and fisheries. National Research Council Publication 551. Washington, National Academy of Sciences–National Research Council, 1957. 137 p.
5. TARZWELL, C. M., *Comp.* Biological problems in water pollution. Transactions of the Second Seminar on Biological Problems in Water Pollution, Cincinnati, Apr. 20-24, 1959. Robert A. Taft Sanitary Engineering Center, 1960. 285 p.
6. MOSS, J. E. Character and control of sea pollution by oil. Washington, American Petroleum Institute, 1963. 122 p.
7. U.S. AGRICULTURAL RESEARCH SERVICE. Proceedings; Federal Inter-Agency Sedimentation Conference, 1963. Miscellaneous Publication No. 970. Washington, U.S. Government Printing Office, 1965. 933 p.

8. U.S. COAST GUARD. Chemical data guide for bulk shipment by water. Washington, U.S. Government Printing Office, 1966. 132 p.
9. KURAK, S. Operation chase. *United States Naval Institute Proceedings*, 93(9):40-46, Sept. 1967.
10. SAX, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Book Corporation, 1968, 1,251 p.
11. CALIFORNIA STATE DEPARTMENT OF PUBLIC HEALTH. California solid waste management study (1968) and plan (1970). Washington, U.S. Government Printing Office. (In press.)
12. BURD, R. S. A study of sludge handling and disposal. FWPCA Publication No. WP-20-4. Washington, U.S. Federal Water Pollution Control Administration, 1968. 326 p.
13. SITTIG, M. Water pollution control and solid wastes disposal. Park Ridge, N.J., Noyes Data Corporation, 1969. 244 p.
14. COMMITTEE ON POLLUTION. Waste management and control. National Research Council Publication 1400. Washington, National Academy of Sciences–National Research Council, 1966. 257 p.
15. AMERICAN CHEMICAL SOCIETY COMMITTEE ON CHEMISTRY AND PUBLIC AFFAIRS, SUBCOMMITTEE ON ENVIRONMENTAL IMPROVEMENT. Cleaning our environment. The chemical basis for action. Washington, American Chemical Society, 1969. 249 p.
16. MAURIELLO, L. J., and L. CACCESE. Hooper dredge disposal techniques and related developments in design and operation. In U.S. Agricultural Research Service. Proceedings, Federal Inter-Agency Sedimentation Conference, 1963. Miscellaneous Publication No. 970. Washington, U.S. Government Printing Office, 1965. p. 598-613.
17. At sea about chemical wastes. *Chemical Week*, 101(16):133-136, Oct. 14, 1967.
18. STEIN, J. E. Observations on the disposal of sodium sludge in the Gulf of Mexico. Unpublished data [Project 147, Reference 56-36T]. College Station, Texas A&M Research Foundation, 1956. 7 p.
19. MARLIL AND POMEROY, CONSULTING ENGINEERS. Engineering study of refuse collection and disposal at San Diego area naval installations; report to Southwest Division, Bureau of Yards and Docks, U.S. Navy, San Diego, Calif., 1966.
20. METCALF AND EDDY/ENGINEERS. Report to the New York State Pure Waters Authority on rail-haul disposal of solid wastes for Westchester County, New York. Unpublished report. New York, Feb. 17, 1969.
21. New sludge barge enters operation for ocean. Disposal company in New York area. *Maritime Reporter and Engineering News*, p.8, Apr. 15, 1969.
22. Sludge disposal at sea. *Civil Engineering*, 38(8):62-63, Aug. 1968.
23. GUARINO, C. F. Sludge disposal in Philadelphia by barging to sea. Presented at 38th Annual Conference, Pennsylvania Water Pollution Control Association, Pennsylvania State University, University Park, Aug. 3-5, 1966.
24. DAUGHERTY, F. M., JR., and J. C. CARROLL. Search for the "Stevenson." *UnderSea Technology*, 9(4):26-30, 46, Apr. 1968.
25. PNEUMODYNAMICS CORPORATION, ADVANCED SYSTEMS DEVELOPMENT DIVISION. Technical Report. Sea disposal container test and evaluation. ASD 4652-F. Atomic Energy Commission research and development report. UC-70 Waste Disposal and Processing. TID-4500. 16th ed. San Francisco, U.S. Atomic Energy Commission, June 15, 1961. 132 p.
26. PNEUMODYNAMICS CORPORATION, ADVANCED SYSTEMS DEVELOPMENT DIVISION. Technical report. Survey of radioactive waste disposal sites. TID-13665. Washington, U.S. Atomic Energy Commission, July 15, 1961.
27. PEARCE, K. W., and J. D. VINCENT. Investigation into the effects of deep sea pressures on waste materials and disposal containers. AERE-M-1254. Harwell, England, United Kingdom Atomic Energy Authority, Sept. 1963. 29 p.
28. Personal communication. George D. Ward and Associates, Consulting Engineers, to D. D. Smith, Dillingham Corporation, June 16, 1969.
29. WHITMAN, REQUARDT & ASSOCIATES. Report to the City of Baltimore Bureau of Sewers on future disposal of digested sludge from the Back River Sewage Works. Baltimore, Dec. 1965. 70 p.

III. ENVIRONMENTAL EFFECTS OF BARGING WASTES TO SEA

Little is known about the immediate effects of solid and liquid wastes on the marine environment, even though a number of pioneer studies have been carried out. Even less information is available on long-term or genetic effects.

An adequate understanding of the response of the marine environment to solid and liquid wastes barged to sea requires continuing investigation programs. To date, funds have been available only for short-term studies often directed to specific questions such as maximum permissible barge discharge rates.

More attention has been paid to the disposal of sewage and sewage sludges, both raw and treated, because of the well-known ability of shellfish to concentrate pathogenic bacteria for human consumption. Sludges barged and discharged to the New York Bight have resulted in high levels of fecal coliform contamination in surf clams[1] and the Food and Drug Administration has recently closed affected areas to further harvesting.[40] In contrast, some 400 tons per day of sewage solids, of which approximately one-fourth is organic, have been discharged through submarine outfalls into Santa Monica Bay, California, with no apparent effects on fish abundance.[2,3] Although the fish were able to avoid possibly harmful concentrations, studies of other Southern California receiving waters indicated severe effects on giant kelp (Macrocystis). The discharge attracted scavengers (sea urchins) that grazed on the mature plants and increased turbidity so that the young kelp did not develop.[4]

The great differences in effects of waste disposal at sea underscore the need for broad and critical research. A brief review and discussion of the literature on environmental effects of waste disposal at sea is presented in Appendix D. Information summarized on the following pages summarizes the state of knowledge of the effects of barged wastes and provides a basis for identifying further research needs. [James L. Verber has revised, updated, or compiled several of the tables in this report. He estimates that nearly 78.5 percent of all wastes discharged at sea are polluted.--*Ed.*]

OBSERVED EFFECTS OF WASTE DISCHARGE OPERATIONS

For ease of discussion, the waste categories are presented in the same order as in the preceding chapter: Dredge Spoils, Industrial Wastes, Sewage Sludge, Refuse, Radioactive Wastes, and Explosives.

Dredge Spoils

The discharge of dredge spoils at sea results in anomalously rapid sediment build-up at the disposal site, in addition to temporary discoloration of the water by turbidity. The sediment build-up would be expected to have significant effects on bottom-dwelling organisms and the life forms dependent upon them in the food chain. Turbidity may be expected to affect various aspects of the water column and the contained biologic assemblage. Reviews of the literature[5,6] regarding the effects of turbidity on marine fish and crustaceans in coastal waters indicate that, prior to Saila's work on a Narraganset Bay dredge spoil disposal site, there was virtually no information available on the subject. Consequently, much of the following discussion is based on the work by Saila, Polgar, and Rogers.[5]

Bottom Sediment Build-Up. The effects of fish and shellfish of rapid local build-up of sediment as the result of dredge spoil disposal can include destruction of spawning areas, reduction in food supplies and vegetational cover, trapping of organic matter (with resultant development of anaerobic bottom conditions), and the absorption or adsorption of organic matter (including oil).

Turbidity. The effects of turbidity on fish and crustaceans can be direct or indirect. Direct effects cause an immediate response or even mortality by suffocation; turbidity can also result in reduced growth and decrease survival of larval stages of fish and shellfish. Saila and co-workers summarized the possible indirect effects of turbidity (and siltation) as follows: (l) reduction in light penetration resulting in reduced photosynthesis; (2) reduction of visibility to some feeding organisms; (3) destruction of spawning areas; (4) reduction of food supplies; (5) reduction of vegetational cover; (6) trapping of organic matter, resulting in anaerobic bottom conditions; (7) flocculation of planktonic algae; (8) absorption or adsorption of organic matter (including oil) or inorganic ions.

The effect of dredge spoils depends in large part on the location and characteristics of the disposal site. For example, if dredge spoils are discharged in inshore waters normally quite turbid because of wave action or the tidal flushing of turbid waters out to sea, then the effects of the associated turbidity (but not necessarily the sedimentation) would almost certainly be negligible.

The situation would be significantly different where spoils polluted with oil, sewage, chemicals etc. are dredged from channels and the confines of harbors and transported to sea for disposal. Once these sediments are discharged in other locations, the resulting turbidity (and associated pollution) can be spread extensively by coastal currents. In this regard, Biggs estimated that disposal of spoils from the approaches of Chesapeake Bay increases the turbidity of the water over an area of about 1 to 1.5 square nautical miles around the disposal site, and that discharged solids are dispersed over a bottom area at least five times that of the defined disposal area.[7]

Saila and co-workers investigated the effects on local fishing resources (particularly the northern lobster) of increased turbidity and siltation in relation to the disposal of dredge spoils in 100 feet of water off Narragansett Bay.[5] The results of biological assays and field experiments showed that adult lobsters were able to tolerate, with no adverse effects, turbidities as high or higher than those actually encountered in the disposal area for periods of time equivalent to those during which the spoils seem to remain in suspension. The one case of high mortality observed in the laboratory bioassay tests was believed to be the result of an unidentified toxic substance contained in the dredging spoil, rather than the concentration of suspended particles.

Interpretation of turbidity measurements at the point of discharge by the same investigation revealed that a fraction of the total turbidity cloud consisting of oils and/or light organic material remained near the surface. If present in sufficient quantities for an adequate length of time, this material could pose a possible pollution threat to the adjacent shore area, particularly during the summer season when a drift from the disposal site is predominately shoreward. The dispersion rate of the remaining turbidity cloud was sufficiently rapid that no direct adverse effects to marine resources of economic importance would be expected.

Comparison of the bottom topography before and after the disposal operation indicated that the volume of sediment added to the volume of excess material present in the site was about 2,004 000 cubic yards, which compares favorably with the 1 960,000 cubic yards dredged by the Corps of Engineers; on the basis of this comparison, most of the dredging spoils remained within the designated disposal area. On the basis of the biological and physical data obtained prior to and during the December 1967 to July 1968 Narragansett disposal operation, Saila and co-workers concluded that the spoil disposal site was acceptable from the point of view of minimizing the damage to locally important marine resources.[5]

Another aspect of dredge spoil disposal has been discussed by Gross, who showed that the volumes of dredge spoils and other sediment-like wastes (construction and demolition debris) disposed of in Long Island Sound and the New York Bight disposal areas represent the largest single source of sediment entering directly into the Atlantic Ocean from North America.[8] From Corps of Engineers records, Gross estimated that the mass of waste solids from the New York City area disposed at sea increased from an average of 6.8 million tons per year during 1960 to 1963 to 8.6 million tons per year for the period 1964 to 1968.

Most of the disposal sites referred to by Gross are in areas where there is little natural deposition of sediment to dilute or bury the man-moved solids that in many cases consist of highly polluted harbor sediments. The effect of these sediments on the biota is not well understood at this time. Gross also points out that disposal of spoil from barges or dredges is significantly different from natural processes whereby river borne sediment is deposited on the ocean floor. Disposal operations are highly localized and involve the instantaneous release of several thousand cubic yards of spoil, which produces a thick layer of sediment that may or may not subsequently be dispersed over a wider area by current action.

Gross emphasized the lack of knowledge regarding the deposits formed by the present disposal operations and the absence of comparative data on existing conditions before disposal operations began. Along these lines, he points out that the present disposal operations are, in effect, gigantic, unplanned experiments and, if treated as such, much could be learned from them.

The Corps of Engineers had earlier recognized the growing need to determine the environmental impact of waste disposal on coastal areas.[9] In 1968, the Chief of Engineers authorized a study of various disposal sites in coastal waters in order to determine the environmental effects produced by the disposal of wastes at sea in these areas. The New York Bight disposal areas were chosen for the initial research because of the large volume of wastes currently being discharged there.

The Coastal Engineering Research Center was responsible for defining the research program. As part of this program, the Sandy Hook Marine Laboratory of the U.S. Bureau of Sport Fisheries and Wildlife has undertaken an intensive two-year biological-chemical field sampling program of the mud, cellar dirt, sewage sludge, and acid disposal grounds in the New York Bight, with the Lamont Geological Observatory of Columbia University carrying out supporting research on water transport and diffusion. [Cooperatively, the Food and Drug Administration has been conducting bacteriological and chemical studies in the same area.--ED.]

Industrial Wastes

The industrial wastes to be discussed below include waste acids, paper mill wastes, chemical wastes, oil drilling wastes, and waste oil. These wastes are typically dissolved or suspended in a water media for bulk discharge at sea from tank barges. In some cases, the material is barreled and dropped over the side.

The majority of studies of the environmental effects of industrial wastes in the sea have been carried out in Gulf of Mexico waters, because the Galveston District of the Corps of Engineers requires filing of laboratory and field studies of the wastes in support of disposal applications. In order to facilitate comparison of the environmental studies of the various types of industrial waste disposal operations, key information from the study results has been summarized (Table 8).

Waste Acid. Studies of the dispersion and environmental effects of acid-iron wastes discharged from barges in the New York Bight disposal area have been investigated by Buelow, Redfield and Walford, Ketchum and Ford, Ketchum, Yentsch, and Corwin, and most recently, by several research workers at the Bureau of Sport Fisheries' Marine Laboratory in Sandy Hook, New Jersey.[1,10-13] These wastes consist of ferrous sulfate and spent sulfuric acid in a freshwater solution, and are the byproducts of a titanium paint pigment manufacturing process.

TABLE 7
DUPLICATE SITES*

Area† Lat. N.	Long. W.	Industrial	Explosive	Radioactive	Dredging	Refuse
		Atlantic				
44° 26′	67° 46′	X			X	
44° 24′	68° 55′	X			X	
42° 25′	70° 35′	X	X	X		
38° 54′	73° [illegible]7′	X	X			
38° 30′	72° 06′	X	X	X		
38° 05′	73° 24′	X	X			
41° 33′	65° 33′		X	X		
		Pacific				
37° 40′	123° 25′		X	X		
37° 35′	122° 50′	X				X

* Compiled by James L. Verber, Food and Drug Administration.

† Sites usually 25 or more square miles.

The studies reported here showed that the toxic effects of these wastes are minimal. Laboratory toxicity tests conducted by Ketchum and co-workers to determine if the acid-iron wastes had any effect on the growth of green plankton algae showed and concentrations of wastes which severely limited growth are found only close to the discharge barge and are diluted rapidly at sea.[12] Zooplankton from samples immediately behind the barge were temporarily immobilized, but recovered rapidly on dilution with unpolluted water a short distance astern of the disposal barge.[10]

Additional findings of the study by Ketchum and co-workers showed that the accumulation of iron hydroxide, resulting from the chemical reaction of the wastes with seawater, was about twice as great in 1957 as that observed in 1948, and 50 percent more

TABLE 8
SUMMARY OF ENVIRONMENTAL STUDIES ON INDUSTRIAL WASTES DISCHARGED AT SEA

Waste Type	Description of Disposal Area				Barging Characteristics				Waste Characteristics	Laboratory Toxicity Studies		
Industrial	Distance from shore (miles)	Water depth (feet)	Latitude	Longitude	Amount of waste/trip	Depth of discharge	Rates of discharge tons/min.	Towing speed (knots)	Given description	Type of test organisms	TLM (range)	Remarks
Spent sulphuric acid	15 from New Jersey coast	80	40° 20'N	73° 40'W	3200 tons 5000 tons	15 feet	18 70	6 7	Fe_2SO_4 (10%) H_2SO_4 (8.5%)	Marine phytoplankton	2.7-35.5 mg/l 6-16 day test duration.	Investigated effects of various concentrations of iron on growth of algae.
Chlorinated hydrocarbons	125 SE of Galveston, Texas	2400	27° 36'N	94° 36'W	1200 tons	12 feet	5	6	Beta-chloropropylene (22%), trichloropropane (5%), isopropylchloride (38%), allylchloride (11%), misc. chlorides (33%), heavy ends (3%), pH - 9.8, specific gravity 0.9 - 1.34.	Marine phyto-, and zoo-plankton, anemones, brine shrimp, bacteria, fish.	0.02-2.5% saturated 0.0005-1g/l, 2-24 hr test duration.	Investigated acute toxicity and inhibition to photosynthesis.
Paper mill wastes (black liquor)	125 SE of Galveston, Texas	2400	27° 36'N	94° 36'W	1300 tons	10 feet	5	6	Paper mill wastes, 47% solids, BOD_5-100,000 ppm Na_2CO_3, Na_2SO_4, NaOH etc., pH - 13. Specific gravity 1.27 at 60°C.	Marine phytoplankton zooplankton.	0.001-1.0g/l, 22 hr test duration.	Investigated acute toxicity and inhibition to photosynthesis.
Ammoniasulphate (mother liquor)	100 S of Freeport, Texas	2760	27° 35'N	95° 20'W	1700 tons		7	4	Ammonium sulfate (23%), nitrogen (8%), carbon (12%), organics (29%) (alcohols, esters, amides), IOD-90 MG/L, BOD_5 57,000 ppm, pH -4.3, S.G. 1.23.	Brineshrimp, top-water minnows.	1.25% by volume 200 ppm, 24 hr test duration.	Acute toxicity.
Waste liquor	70 S of Freeport, Texas	960	27° 48'N	94° 54'W	2400 tons		5-24	6	Na_2S (Na_2S_2) (6%) (Na_2S_2) NaHS 1% S (total) (6%), NaCl (21%), organic 2%, solids (dissolved and suspended), specific gravity 1.24 at 60°C.	Marine phytoplankton, top-water minnows, brine shrimp.	0.0005-0.18% by volume, 24 hr test duration.	Acute toxicity.
Chlorinated waste liquor	125 SE of Galveston, Texas	2400	27° 36'N	94° 36'W	1400 tons (proposed)		13-25 (recommended)	5 (recommended)	(Organic waste) chlorinated organics (10-15%), inorganic salts (Na_2SO_4) (5-6%); (acid) chlorinated organics (1%), sulfuric acid (10-15%), nitric acid (0.1%).	Marine phytoplankton, top-water minnows, brine shrimp.	0.02-0.64% by volume, 24 hr test duration.	Acute toxicity, waste acid more toxic to fish than brine shrimp.
Sodium sludge (containerized)	110 S of Galveston, Texas	2400	27° 36'N	94° 36'W	15 55-gal. drums (500-570 pounds per drum)	Surface	Variable	10	Metallic sodium (75%), calcium (24%), barium, magnesium, potassium (1%).			
Pesticides	95 SSE of Galveston, Texas	720	27° 49'N	94° 30'W	50 55-gal. drums per trip	1200 ft	1 barrel/2 mins. (600' intervals on bottom	3	Anilines (chlordaniline, monochlorobenzene), liquid organics (methanol, p-xylene, chlorobenzene), dry chemicals–insoluble (*thiram*, *thiram-E*, *thionex*, *zineb*, *ferbam*, *monuron*, carbon disulfate).	Minnows, largemouth bass, salmon, bluegills, mosquito fish, channel catfish, bluegill sunfish.	1-135 mg/l, 48-96 hr test duration.	Toxicity values obtained from literature.
Caprolactam wastes	35 S of Sabine Bank Light	60	29° 10'N	93° 40'W								

TABLE 8
SUMMARY OF ENVIRONMENTAL STUDIES ON INDUSTRIAL WASTES DISCHARGED AT SEA–(Continued)

Waste Type	Reported Field Observations			Mixing Characteristics			
Industrial	**Physical-Chemical**	**Biological**	**Observed effects**	**Initial dilution**	**Diffusion coefficient cm^2/sec.**	**General study conclusions**	**References**
Spent sulfuric acid	pH, iron concentration (0-60'), wind, weather, sea state.	Plankton (0-60'), benthic organisms, pelagic fish (30').	Water discoloration, plankton temporarily immobile, iron settled rapidly from surface layer, no appreciable accumulation of iron found in bottom sediments.	1:5,000	$2{\cdot}9 \times 10^4$	Mixing and diffusion of wastes occurs rapidly in the wake of the barge. No evidence to indicate adverse effects. Each new proposed waste disposal operation needs careful study prior to allowing ocean disposal.	1, 10, 11, 12, 40
Chlorinated hydrocarbons	Temp. (0-900'), salinity oxygen, waste concentration (0-500'), surface currents, wind, weather, sea state, bottom mud.	Plankton, O_2 evolution, C_{14} uptake, chlorophyll-A, visual inspection of *sargassum* weed.	Water discoloration: fish, plankton killed on direct contact of waste, no harmful effects seen after 2-4 hrs. Bulk of waste sank. Low diffusion of waste at depth.		2.5×10^3 (average)	Disposal of toxic wastes at sea can be accomplished with only a slight effect on organisms in the biomass within a limited oceanic area. Each new waste disposal operation needs careful study prior to sanctioning it.	16, 17, 18, 19
Paper mill wastes (black liquor)	Temp. (0-900'), salinity (0-600'), waste concentration surface samples, pH, oxygen (0-600'), wind, weather, sea state.	Plankton (0-100'), O_2 evolution, C_{14} uptake, chlorophyll-A.	Slight water discoloration. No mortality to marine life. Bulk of waste sank.	1:300,000	2.5×10^3 (average)	Disposal of "black liquor wastes" in the deep sea can be accomplished without determinable effects on marine biota. Ultimate disposal is expected to be accomplished by bacteria. Advisable to monitor each separate load of waste to determine toxicity in laboratory.	15
Ammoniasulphate (mother liquor)	Waste concentration (0-150')		No fish mortality. No floating oil. Bulk of waste sank. Maximum waste concentration at depth.		9×10^2	No undesirable effects were observed. Diffusion great enough to ensure good dispersion to minimize harmful effects to biota.	22
Waste liquor	Waste concentration (0-150'), temp., salinity pH, oxygen, (0-600').	Plankton, pelagic fish, *sargassum* weed communities.	No evidence of subsurface maximum waste concentration.	1:10,000-1:100,000 in 2 hrs		Disposal should produce no significant mortality in the biota, nor any prolonged effects.	21
Chlorinated waste liquor						No significant mortality would be expected from disposal of this waste in the open ocean. It is suggested that a full-scale disposal operation be properly monitored and continued to verify preliminary study results.	20
Sodium sludge (containerized)	pH	Plankton, fish, *sargassum* weed.	No mortality to fish. Flying debris hazardous to disposal personnel. 30% mortality to plankton due to collection methods.			Explosions caused by reaction of sodium with seawater had no significant effects on *sargassum* and zooplankton populations. Absence of fish-kiln was probably due to barrenness of disposal area.	23
Pesticides				100:1	0.002×10^3	Consideration of available toxicity and diffusion data from literature sources indicate that the zone of water containing toxic concentrations of waste surrounding each disposal drum will be limited in extent and duration and will not endanger motile aquatic life in the disposal area to a significant degree.	24
Caprolactam wastes	Temperature (0-60'), salinity (surface), wind, weather, sea state.	Plankton, bottom samples, C_{14}, chlorophyll-A,-B,-C.				Limited scale (one day) of survey precluded any significant results. Recommend future surveys be conducted on 3-day basis for better results.	

than that observed in 1950.[12] This was less than might have been expected, however, from the increase in the discharge rate that had occurred over the same period. No evidence was found to indicate that the general turbidity of the waters caused by the iron precipitate has increased outside the general disposal area. Ketchum[14] and Wuestefeld[9] reported that, since establishment of the acid-iron disposal operation in 1948, a concentration or bluefish has developed on the outer boundaries of the disposal area, thus creating a highly popular sport fishery that did not previously exist.

Paper Mill Wastes. This waste is the so-called 'black liquor' produced by the sulfate process used in paper manufacture; it includes sodium carbonate, sodium sulfate, sodium hydroxide, and other chemicals. The wastes described by Hood and Abbott[15] were discharged off the Texas coast in 1955 and contained about 45 percent solids, were water soluble but quite viscous, and had a pH greater than 13. Laboratory studies using four species of phytoplankton showed the concentration of black liquor affecting photosynthesis (i.e., threshold toxicity) was about 0.05 grams per liter, and the lethal concentration was on the order of 1 gram per liter. Tests on zooplankton produced no acute toxicities in concentrations up to 0.4 grams per liter; greater concentrations were not tested because it was impossible to observe the zooplankton as a result of the opaque characteristics of the wastewater mixture. Visual observations at sea confirmed the non-toxic character of the wastes, as zooplankton in samples taken immediately astern of the discharge barge were observed to be swimming about normally.

Field evidence also showed that the absorbent component of the waste sank almost immediately, leaving only a slight discoloration at the surface that was visible for only 30 to 40 minutes after discharge. A minimum dilution ratio of waste to water immediately behind the barge was calculated to be on the order of 1 to 300,000 or a concentration of 0.03 grams of waste per liter, which is well below the values given previously for threshold and acute toxicity on phytoplankton. Bacterial action should result in the ultimate disintegration of the organic components of the black liquor wastes while the inorganic fraction, principally sodium sulfate, would rapidly lose its identity when mixed with seawater.

Chemical Wastes. For convenience of discussion here, the chemical waste subcategory is divided into chlorinated hydrocarbons, ammonia sulfate, waste liquor, sodium sludge, and pesticides.

Chlorinated Hydrocarbons. The chlorinated hydrocarbon waste category includes betachloropropylene, trichloropropane, isopropylchloride, allychloride, miscellaneous chlorides, and other constituents discharged by chemical and petrochemical plants. The disposal operations discussed here are confined to the Gulf of Mexico. Although wastes containing various percentages of chlorinated hydrocarbons are discharged off the Atlantic and Pacific coasts, their environmental effects have not been investigated primarily because in those areas such studies are not a prerequisite for obtaining a disposal permit.

Four separate chlorinated hydrocarbon disposal operations in Gulf waters have been studied by Hood and his associates[16-18] at the Texas A & M Research Foundation. Their work included field and laboratory investigations of the effects of these wastes on various marine organisms, with emphasis on phytoplankton, zooplankton, and fish. Observed effects at the disposal site included sinking of the bulk of the waste, discoloration of the water, and the death of fish and plankton on direct contact with the undiluted waste. After two to four hours, the surface waste field was found to be sufficiently diluted so that no effect on marine life was observed.

Because the inherent patchy distribution of the microorganisms at sea makes it difficult to obtain statistically significant results, the effects of various toxicity levels on phytoplankton and zooplankton were tested by Hood under controlled laboratory conditions. Inhibition to photosynthesis and respiration caused by the wastes was determined by using standard oceanographic procedures for measuring carbon-14 uptake and oxygen evolution. Comparison of the results with those obtained from uncontaminated control samples maintained under identical laboratory conditions provided an index of inhibition. Acute toxicity tests were also conducted on the plankton and various species of fish. Results of the laboratory toxicity studies showed that the inhibition to photosynthesis and respiration is a much more sensitive and meaningful measure of the toxic effects of organic contaminants in seawater than acute toxicity tests on organisms such as fish.

The effects of wastes on organisms endemic to the disposal sites was assessed in the field by examining the flora and fauna associated with the seaweed, Sargassum, present both within the outside of the disposal area. It was found that direct contact with the undiluted hydrocarbon wastes at the point of discharge was generally lethal to the small crabs, shrimp, fish, snails, etc., but in most cases samples taken in the disposal area showed conditions had returned to normal within three to eight hours.[15-19]

With regard to diffusion and dispersion of the hydrocarbon wastes, Hood and Stevenson estimated that about seven square miles of surface area would be affected by a single disposal operation.[17] Further their work indicated that within three to nine hours, the wastes in the surface layers were diluted to levels below the limit of detection by the analytical method used.[18,19] In contrast to this, slow dispersion of the wastes occurred at depths from 50 to 500 feet. For example, at one station the waste concentration at 500 feet was roughly equivalent to that observed at the surface in the actual disposal wake 42 hours earlier.[16] Because of the possibility of these waste-laden waters working their way shoreward to bottom fishing areas or regions of upwelling, it was recommended that future disposal areas should be located seaward of the 400 fathom line.

Hood concluded that chlorinated hydrocarbon wastes could be discharged at sea with only minor adverse effects on marine organisms within the dispersal area.[18,19] It should be pointed out, however, that Hood's work did not examine the possible effects of the wastes at depth or of bottom contamination on benthic organisms, even though samples of bottom mud within the disposal area contained from 10 to 100 percent of the original surface concentration of hydrocarbon waste.[16]

Ibert, Wilson, and Harding carried out laboratory tests on the toxicity of two chlorinated hydrocarbon wastes produced by a chemical plant; this study was in preliminary support for an application for marine disposal off the Texas coast.[20] The tests, which used top-water minnows, brine shrimp, and various phytoplankton, measured both the median toxicity level at 24 hours and the critical concentration range, defined as that dilution range between which there is no mortality on the one hand and no survival on the other. In the case of the test plants, 50 percent survived at concentrations of 0.05 to 0.5 percent by volume on 24-hour exposure to the hydrocarbon wastes, and the waste, which included dilute sulfuric acid, was somewhat more toxic, i.e., 50 percent survival at concentrations of 0.02 and 0.05 percent by volume. This greater toxicity should be greatly reduced in a marine disposal operation because of the rapid neutralization of sulfuric acid which occurs in seawater.[10]

Ibert and associates estimated that the waste would be diluted below the 0.006 percent concentration range within an hour by using a pumping rate between 8 and 15 tons per hour while underway at five knots, and concluded that no significant mortality would be expected from the disposal of either waste in the open ocean.

Waste Liquor. Ibert and Harding carried out laboratory and field studies on an industrial waste liquor being discharged off the Texas coast.[21] The waste consisted of various compounds of sodium, hydrogen, and sulfur, along with sodium chloride in an aqueous solution (specific gravity greater than 1.25) that was completely miscible in seawater. On the basis of the laboratory toxicity studies, they concluded marine disposal would produce no significant mortality, nor any prolonged deleterious effects, nor would the concentrations of the waste persist beyond two hours after discharge.

Because the wastes were about 25 percent more dense than seawater, the bulk of the materials sank rapidly from the surface layer, but to the depth covered by sampling (164 feet) there was no evidence of plunging of the wastes in an undiluted stream. Further dilution and dispersion of the wastes were expected to occur on the bottom but sampling was not carried out to confirm this fact.

The reported maximum value of the waste concentration 1.5 miles astern of the barge was less than one in 10^5 (.001%), which was within a factor of two of the minimum value of TL_M reported earlier for the phytoplankton used in the toxicity tests.[21] In spite of these favorable results, it was recommended that future operations use a significantly reduced pumping discharge rate per mile of vessel track in order to insure adequate dispersion under all oceanographic conditions.

Ammonium Sulfate Mother Liquor. MacSmith studied the effects of ammonia sulfate mother liquor on brine shrimp and minnows in the laboratory, as well as the diffusion of these wastes during discharge.[22] This waste material is saturated with ammonium sulfate and contains about 10 percent organic carbon as alcohols, amides, esters, etc.; it is generated in obtaining ammonium sulfate from sulfuric acid in a fertilizer manufacturing process. Smith's work included chemical analyses, biodegradability and toxicity studies, and preliminary diffusion calculations, as well as sampling at sea to determine actual diffusion.

On the basis of the preliminary diffusion and toxicity studies, it was concluded that the wastes would not produce adverse effects on the environment or organisms within the disposal area. A trial disposal operation verified the predictions that diffusion would be sufficiently rapid to minimize the harmful effects to the biota.

Sodium Sludge. Stein reports a study of the disposal of sodium sludge off the Texas coast.[23] The sludge consisted of approximately 75 percent metallic sodium and 24 percent metallic calcium, and was a waste product from a petrochemical plant. The barreled sodium sludge was punctured and dropped overboard; when seawater made contact with the sodium, the drums exploded (Figure 7). Field observation and sampling indicated that the explosions and elevated pH (resulting from the interaction of the sodium with seawater) had no significant effects on the Sargassum and zooplankton communities as compared to those in the control area. An absence of floating dead fish may have been due to the barrenness of the area.

Corps of Engineers records indicate that on two occasions unpierced barrels loaded with sodium sludge have been retrieved from Gulf waters by fishermen. In these cases it is almost certain that the disposal operators did not dispose of the barrels in the designated disposal area.

Pesticides. Waller studied the probable environmental effects of the proposed marine disposal of wastes from a Gulf Coast plant that manufactures herbicides and fungicides.[24] The waste included chemicals of the following types: anilines (primarily chloroaniline and aniline with small amounts of monochlorobenzene); liquid organic solvents (methanol, p-xylene and chlorobenzene); and dry chemicals including Thiram, Thiram- E, Thionex, Zineb, Ferbam, Monuron, and carbon disulfate. Because of their toxic nature, these wastes are disposed of in weighted steel drums. To facilitate discharge and dispersal along the bottom, a small air space is left in each drum to ensure deformation and rupture of the drum on the ocean floor.

Waller evaluated toxicity data on these waste materials on the basis of the available literature, and concluded that:

> The herbicides and fungicides are generally more toxic than the liquid organics. These dry chemicals, however, have a very low solubility so that once in solution a relatively low dilution ratio (on the order of 100:1) will reduce the concentration below the median tolerance limits (TL_M). . . . In addition, the susceptibility to biodegradation and chemical instability in an aqueous environment would further reduce localized toxic conditions.[24]

A mathematical model was developed by Waller to consider the dissolution of the slightly soluble solid material with subsequent diffusion into the surrounding seawater and simultaneous chemical degradation. He calculated that, at a discharge rate of one barrel every two minutes from a barge moving at three knots, the drums would be spaced at 600-foot intervals on the ocean floor. In the case of a waste material dissolving over a period of one year, calculations showed that, based on an eddy diffusion coefficient of 2 cm^2/sec, a 100 to 1 dilution is reached at a maximum distance of 54 feet, 30 days after discharge. He considered this approach to be conservative in that no allowance was made for biological degradation or strong currents that could greatly increase the dispersion.

No actual at-sea tests were conducted on this disposal operation. Therefore a follow-on at-sea monitoring program would be highly desirable, particularly in light of potential adverse effects.

Drill Cuttings and Drilling Muds. The rock chips produced by the bit in drilling an oil well are termed drill cuttings. On offshore drilling platforms along the southern California coast, these cuttings are generally washed and discharged below the rig. Although the resulting solid waste accumulation is volumetrically of little significance because of its possible effect on marine life it has been discussed by Turner, Carlisle, and Ebert who reported that the cuttings were found to have no effect, either adverse or beneficial, on the environment.[25,26] Turner and co-workers suggested that, if the cuttings were to be disposed of several hundred feet away from the drilling platform and capped with stones or other rubble, they could provide an artificial habitat for sportfishing.[25]

The disposal of drilling muds and cuttings in deep water from a barge has also received cursory investigation by the THUMS Long Beach Company in cooperation with several Federal and State agencies, including the Corps of Engineers.[27] Observations on the disposal operation consisted of aerial photographs and visual inspection at the sea surface to assesss the extent of surface contamination. On the basis of the one-day study, it was concluded that the disposal operation posed no threat to the environment.

Waste Oil. Although environmental studies have not been made on the single industrial waste oil disposal operation noted during the survey, some very significant work has been carried out on the wastes from tank cleaning operations conducted by oil tankers at sea. Based on the earlier work of ZoBell regarding the oxidation of hydrocarbons by marine bacteria, Moss has shown the importance of discharging these wastes in a finely divided or atomized form in order to optimize bacterial degradation.[28,29] Moss' calculations show that the full quantity of waste oil (at an average concentration of 0.13 milligrams/liter) resulting from cleaning the tanks of a 45,000 dwt tanker underway at 16 knots would be oxidized by bacteria in 2 to 4.5 days, depending on whether the wastes were discharged continuously over a 24-hour period, or discharged as fast as the tanks were cleaned.[29] The broader aspects of the environmental effects of oil in the marine ecosystem have been summarized recently by Holcomb and Blumer.[30,31] Holcomb concludes that "... little is known about the long-term effects of oil in the marine environment."[30, p. 204]

Discussion. The information indicated in the preceding paragraphs when summarized represents virtually everything we know of the environmental effects of industrial wastes discharged at sea from barges (Table 8). This minute body of information is totally disproportionate with both the amounts of wastes handled and the potential damage that these wastes can do. It should be noted that the limited scope of the work accomplished to date reflects the economic and environmental constraints which have been applied in the past. There is abundant evidence that these constraints are changing so that it is reasonable to assume that future marine disposal of wastes will be limited to those operations which have been shown not to cause damage.

Sewage Sludge

Sewage sludge discharged at sea is the residual from municipal sewage treatment plants and is generally 3 to 10 percent solids by weight. It is discharged from tank barges at one disposal site in the New York Bight and another off Cape May, New Jersey. There are no similar operations on the Gulf or Pacific coasts, although large volumes of sludge are discharged in southern California coastal waters through submarine outfalls.

The effects of sewage sludge on the marine environment have been investigated by Buelow and associates,[1, 32-34] and for the southern California outfalls, by Carlisle, North, Pearson, Rittenburg, Gunnerson, Brooks, and Grigg and Kiwala and many others.[3,4,35-39]

The environmental effects of barge disposal of sludge in the designated sites in the New York Bight and off Cape May, New Jersey (Figure 2) were studied by Buelow and associates at the U.S. Public Health Service's Northeast Technical Services Unit, FDA Laboratory.[40] This study was the outgrowth of the increased concern by Federal and State health agencies and the shellfish industry over the possible contamination of the commercial surf clam beds adjacent to the sewage sludge disposal grounds. Of particular concern was the possibility that the surf clams might accumulate and concentrate bacteria, viruses, and other toxic substances present in the sludge; these substances could, in turn, be transmitted to consumers of the shellfish. Results of this study indicate that sludge settles rapidly to the bottom and that, except in the immediate wake of the barge discharge, the highest coliform contents occurred in the samples from the near-bottom water.

Because of the preliminary nature of their field investigations, Buelow and co-workers were unable either to approve the present disposal sites or to recommend their relocation. Preliminary results, however, of the current Corps of Engineers study of the New York City sludge disposal area indicate that, because of the high bacterial contamination found in surf clams adjacent to the sludge disposal grounds[40] harvesting clams should be prohibited from within a 6 mile radius of the center of the disposal grounds.

Buelow has also concluded that the sludge from the disposal area off Cape May poses a potential threat to existing commercial surf clam beds and shellfish beds located to the south and west of the present disposal site, as they are in a direct line to receive sludge carried by the prevailing tidal currents. In addition, Buelow pointed out that the location of the New York sludge disposal area within a few miles of the head of the Hudson Submarine Canyon, and the apparent southerly drift of the sludge on the bottom towards the head of the canyon, constitute a potential threat to the lobster and red crab populations which may breed in the shallower portions of the canyon.[1]

The work on several major southern California submarine sewage outfalls by the various investigators cited above demonstrated the presence of coliform concentrations in the upper layer of bottom sediment adjacent to the outfalls. In connection with these studies, Gunnerson has divided the various factors, which are important in reducing bacterial populations in seawater, into three categories[37]: (1) bacteriologic factors endemic to the marine environment—these include competition for food, predation, salinity, sunlight, temperature, pressure, etc. All of these factors may be combined into a single factor—namely, mortality; (2) settling behavior of suspended solids—this is dependent on the size, shape, flocculating characteristics, and density of the sludge particles, which, in turn, are a function of the type of sewage treatment process. Particle characteristics are also important because the bacteria are concentrated within or on the particles; (3) dispersion of the effluent field—this takes place as the sludge field moves downstream from the outfall.

Gunnerson set up a simple mathematical expression relating these three factors.[37] Using this relationship in an investigation of the persistence of coliform bacteria in the primary effluent from the Hyperion Outfall off Los Angeles, he showed that sedimentation is, by far, the most important factor in the disappearance of coliform bacteria from the surface layer of the water column.

The results of work by North and by Grigg and Kiwala to investigate the environmental effects of sewage disposal from the Whites Point outfall in 65 to 195 feet of water off Los Angeles reveal that, shoreward of the 10-fathom curve, large-scale ecological changes have occurred.[4,39] For example, many species that normally occur over rocky substrates at these depths (e.g., kelp, lobster, abalone, and many species of fish) are either rare or no longer present. The length of coastline affected by the sludge deposit has spread from two miles in 1954 to six miles in 1969, at least a three-fold increase in length in 15 years. In contrast, Carlisle reports that sewage sludge disposal from the Hyperion outfall in 320 feet of water in Santa Monica Bay has apparently had no measurable effects on fish abundance.[3]

In summary, studies have indicated that sewage sludge in large concentrations destroys the marine habitat in the immediate vicinity of the sludge field; that the sludge drifts slowly along the bottom because of currents; that coliform and related toxic substances are potential threats to shellfish within a radius of 5 to 10 miles of the site; that the toxic substances and coliform bacteria associated with the sludge are concentrated in bottom sediments; and that a great deal more field and laboratory work is required to accurately predict the detailed behavior of the sludge and the probable environmental response.

Refuse

Although there have been no sizeable municipal refuse disposal operations at sea from the United States in the past 25 years,[41] several U.S. coastal cities (including New York, Oakland, and San Diego) had previously dumped their refuse at sea. These operations were generally unsatisfactory because of the associated fouling of beaches and resultant public disfavor and eventual preventative legal actions. The results of the present survey show, however, that in 1968 there was small- scale disposal at sea of refuse from military installations in Long Beach and San Diego and from a cannery in the San Francisco Bay area (Chapter II). Black also reports that the city of Charlotte Amalis on St. Thomas Island, Virgin Islands, in 1962 began disposing at sea a daily average of 280 cubic yards of refuse.[41]

Studies associated with the past disposal of refuse at sea have been either investigations to establish the sources of wastes found on public beaches, or examinations of the economic and technical feasibility of conducting such disposal operations.

Only in the last two or three years have there been serious attempts to determine the possible environmental effects of disposal of refuse and related solid waste in the ocean, These studies[42-44] are an outgrowth of the several new methods that have been proposed to facilitate effective marine disposal.[45-50] Probably the most comprehensive study to date is that directed by Dr. Melvin W. First and conducted jointly by the Harvard School of Public Health and the University of Rhode Island's Graduate School of Oceanography with funds from the U.S. Public Health Service and the Atomic Energy Commission.[42,51] Systems analysis techniques were employed in this study to evaluate several distinct but interrelated aspects of the feasibility of utilizing shipboard incinerators in connection with marine disposal of refuse from Boston.

Besides defining costs and operating characteristics of the incinerator vessels, the study examined what effects the incinerator residues would have on a variety of marine organisms. Both acute and chronic toxicity tests were carried out on species ranging from phytoplankton and lobster larval to flounders and clams. Oceanographic studies were made in order to predict the movement of incinerated solid wastes along the bottom under various conditions. Meteorological studies were conducted to determine safe burning sites for every weather pattern likely to be experienced in the general offshore region proposed for the disposal operations.

Oviatt has summarized the studies on the toxic effects of incinerator residue on selected marine species.[43] Short- and long-term toxicity tests were performed on a series of organisms including clams, shrimp, scallop, lobster larvae, and fish. The quahaug (*Mercenaria mercenaria*) was the most resistant; 90-day quahaug bioassays in residue concentrations up to 10 percent by weight failed to produce mortalities or significant changes in growth. The common mummiehog survived with no mortalities in 40-day bioassay tests with residue concentrations up to 30 percent by weight. First- and second-stage lobster larvae and the common prawn did not experience significant mortality in residue concentrations of 1 percent or less. Of all the fish species tested, the juvenile menhaden was the most sensitive with less than 50 percent surviving 50 days of exposure to the incinerator residue in concentrations exceeding 1 percent by weight. The sea scallop was the most sensitive bottom organism tested and significant mortality occurred in concentrations greater than 3 percent by weight. Additional work has been described by Rogers.[44]

The toxicity effects reported were not considered a serious drawback to the proposed disposal program because calculations show that about 25 years of daily disposal of 500 tons over a 1-square-mile area would be required to equal the toxic level of one present residue concentration.

Oceanographic studies showed that incinerator residue (including cans) in 50 feet of water would drift under storm conditions with the net movement caused by the combined effects of the wave orbital velocity associated with passing waves and the tidal currents found in the area.[52] Once the cans and other debris begin to rock back and forth as a result of wave orbital motion, weak but steady tidal currents cause a net movement in the direction of the current. Calculations indicate that wave heights greater than 3 feet can move debris down to 50 feet, wave heights above 9 feet can move debris at 100 feet, and wave heights above 12 feet can move debris at 200 feet. On the other hand, burnt cans disintegrate at a fairly rapid rate so that, at depths beyond 100 to 200 feet, disintegration was likely to occur long before the object moved a significant distance.

Observations on a simulated incinerator residue disposal site in 180 feet of water were conducted in 1968 with the aid of a research submarine. Some 25 dives were conducted to observe and photograph marked objects planted on the bottom and the effects of actual incinerator residue deposited earlier in the study area.[53] The general conclusion was that incinerator wastes on bottom in 100 to 200 feet depths off Boston would not drift significantly.

The disposal of municipal refuse and garbage at sea (baled or otherwise caused to sink) has received serious consideration in the past year by such major U.S. coastal cities as New York, Philadelphia, and San Francisco,[49] and increasing pressure for marine disposal is a certainty as the coastal population grows. At present, virtually no information is available on the probable effects on the marine environment of a large- scale disposal operation. Considerable work would be necessary before undertaking such disposal. In this regard, it is worthwhile to note that the results of a recent study on the disposal of solid wastes from Westchester County, New York, conducted for the New York State Pure Waters Authority,[54] showed that barge-haul and disposal of baled refuse at sea was technically feasible and less costly than rail-haul and sanitary landfill or incineration. At-sea disposal was not recommended, however, "... because of the difficulty in proving that it will not unbalance the ecology of the area...".[53] In Philadelphia, a well publicized application for a permit to dispose of refuse at sea was prepared. No action has been taken on this proposal.[54 p. 4]

In considering the uncertainties inherent in evaluating the ecological impact of solid waste disposal at sea, it is important to note that the Bureau of Sport Fisheries and Wildlife (under a cooperative agreement with the Bureau of Solid Waste Management) is investigating the beneficial uses of marine disposal of refuse specifically, the costs and benefits of building artificial fish habitats from wastes such as rubber tires and baled refuse.[56] Such baled refuse might also provide food for fish.

Radioactive Wastes

The environmental effects and dispersion of radioactive wastes in the ocean have been the subject of considerable research over the past 20 years. Although containerized radioactive wastes were not disposed of at sea in 1968, much of the knowledge stemming from previous research is pertinent to an understanding of the environmental effects of present marine solid waste disposal operations. Disposal at sea resumed in 1969, therefore, even though a comprehensive review of the voluminous literature on the subject was beyond the scope of this study, selected basic studies particularly pertinent to other marine disposal operations were reviewed and are discussed in this section. The reader interested in more detailed information is referred to the references cited later in this section.

In 1956, the National Academy of Sciences-National Research Council (NAS-NRC) organized a series of committees to study the various aspects of the biological effects of atomic radiation. In the report of the Committee on Oceanography, Revelle and associates presented a critical evaluation of the state of knowledge available at that time regarding the physical, chemical, biological, and geological processes involved in the interaction of radioactive wastes with the marine environment.[57] On the basis of this evaluation, it was concluded that most of the physical and biological processes in the ocean were too poorly understood to permit precise predictions of the results of the introduction of a given quantity of radioactive materials at a particular location in the sea. The Committee proposed that several basic problem areas should be attacked in the future, in order to obtain the necessary knowledge required for assessing the effects of radioactive waste disposal in the ocean. These include: dispersion in the upper mixed layer of the sea; circulation in the intermediate and deep ocean layers; exchange of water properties between the surface and deeper layers; sedimentation processes; effects of biosphere on the distribution and circulation of elements; uptake and retention of elements by organisms used as food for man; effects of atomic radiation on populations of marine organisms.

In 1958, the U.S. Bureau of Commercial Fisheries, U.S. Atomic Energy Commission, and the Office of Naval Research jointly requested that the NAS-NRC Committee on Oceanography undertake a detailed evaluation of the problems of disposal of both liquid and solid low-level radioactive wastes into the ocean off the Pacific, Atlantic, and Gulf coasts of the United States. The primary objectives of this program were to provide estimates of the level of radioactive wastes that could safely be disposed of at sea, and the most satisfactory locations and methods for disposal to insure that the present or future use and enjoyment of the resources of U.S. coastal areas would not be impaired.[58]

Of the several potential hazards accompanying sea disposal of radioactive wastes, the most critical from the point of view of the NAS-NRC program is the possibility of return of the radioactivity to man. Next in importance is the possible damage to marine organisms from exposure to radioactive wastes. Two avenues through which damage could possibly occur are: (1) transport of the radioactive wastes from the disposal sites to the coastal zone, thereby curtailing the present or future use and enjoyment of the resources of the region; (2) uptake of the radioactive wastes by one or more of the trophic levels in the marine biota, with possible return to man via commercially important fish and shellfish.

Three reports have been published as a result of the NAS-NRC studies.[58-60] Carritt and co-workers studied physical diffusion of low-level radioisotopes from containerized waste disposal areas located in relatively shallow waters on the continental shelf.[58] Pritchard and associates investigated the problem of physical diffusion associated with the disposal of low-level liquid radioactive wastes discharged in the surface layer of the sea from nuclear vessels.[59] The study by Isaacs and co-workers concentrated on the biological aspects of the problem, including the possibility modification of the ecological regimen; in particular they considered the effects of the containerized wastes in attracting fish and other marine organisms, and the subsequent transfer of the wastes from the deeper waters via biological processes.[60]

The Pritchard report summarized the key factors that determine the fate of radioactive material introduced into the marine environment and showed a schematic presentation of the step-by-step considerations that should be made in evaluating the suitability of any marine locale as a receiver of nuclear wastes (Figure 14). The general procedure is the same whether the evaluation concerns containerized wastes or liquid wastes discharged from outfalls and vessels. A similar sequence of considerations is appropriate in the evaluation of potential oceanic sites for non-radioactive solid waste disposal.

In the Carritt study, a series of 28 shallow water disposal sites were proposed for the Atlantic and Gulf coast area.[58] For these sites, the maximum allowable annual rate of disposal for a site two miles in diameter was calculated to be 250 curies of stron-

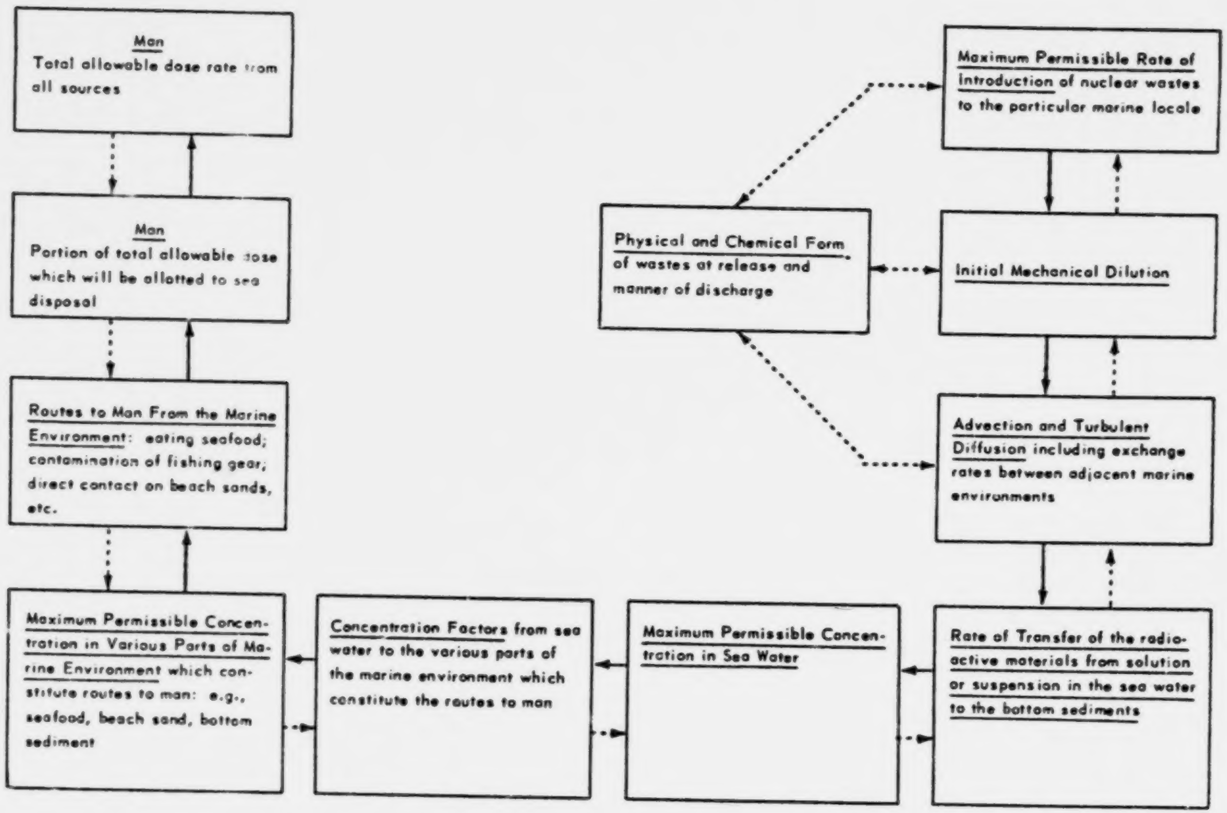
Man
Total allowable dose rate from all sources
Man
Portion of total allowable dose which will be allotted to sea disposal
Routes to Man From the Marine Environment: eating seafood; contamination of fishing gear; direct contact on beach sands, etc.
Maximum Permissible Concentration in Various Parts of Marine Environment which constitute routes to man: e.g., seafood, beach sand, bottom sediment
Concentration Factors from sea water to the various parts of the marine environment which constitute the routes to man
Maximum Permissible Concentration in Sea Water
Rate of Transfer of the radioactive materials from solution or suspension in the sea water to the bottom sediments
Maximum Permissible Rate of Introduction of nuclear wastes to the particular marine locale
Physical and Chemical Form of wastes at release and manner of discharge
Initial Mechanical Dilution
Advection and Turbulent Diffusion including exchange rates between adjacent marine environments

FIGURE 14. Schematic presentation of the step-by-step considerations that should be made in evaluation the suitability of any marine locale as a receiver of nuclear wastes. (From Pritchard *et al.*[59])

tium-90 or its equivalent. This value is based on a modification of the diffusion equation for the continuous release of a contaminant at a known rate, under a steady-state condition of supply from a ruptured container containing not more than two curies of strontium-90 or its equivalent. The effects of adsorption by bottom sediments and uptake by marine organisms are not considered in this equation.

The Isaacs report set the maximum permissible number of disposal sites off the U.S. and Canadian Pacific coast at 40, with a maximum of 20 between the Mexican border and the Columbia River. In determining the allowable rate of disposal for the recommended sites, Isaacs and associates considered two general situations. For each disposal site located below the region of growing marine plants (euphotic zone), yet within the vertical range of human food fish and other human food organisms, they recommended that packaged radioactive wastes (Figure 12) can be disposed of "...at a rate equivalent to 150 curies per year of material that has a maximum permissible concentration in sea water (MPCC) of 1.5×10^{-5} microcuries per kilgram, with soluble isotopes not exceeding 40 millicuries per drum and insoluble isotopes not exceeding 0.5 millicuries per drum on an average basis."[60]

In depths below the vertical limit of human food fish, the annual limit for radioactivity in each disposal area was given as:

$$Q = 5 \times 10^6\ (\overline{MPCC})\ (d - b)$$

where Q is the maximum disposal quantity of the isotopes in curies per year, $\overline{MPCC}$ is the weighted mean allowable concentration (in micro curies per kilogram) of the isotopes in seawater, d is the depth of the disposal area in meters, and b is the limiting depth of a human food organism in meters. On the basis of this relationship, a disposal location situated in 4,400 meters (14,436 feet), with b set at 2,400 meters (7,874 feet), would have an allowable disposal of 150,000 curies per year.[60]

From an evaluation of the environmental data associated with the two existing disposal sites (one off San Francisco in the vicinity of the Farallon Islands and one in the Santa Cruz Basin), Isaacs and colleagues recommended that the Santa Cruz basin site should be relocated to the Santa Barbara basin.[60] This change was on the basis of the latter's anaerobic properties, higher rate of sedimentation, bottom characteristics and sparce amount of benthic life, and water circulation. This example points out the fact that the deepest location farthest from shore is not necessarily the best site for disposal of a given waste material.

All of the past efforts to assess the potential hazards of radioactive disposal at sea have been hampered by lack of factual data and the complexity of the physical and biological processes in the ocean. As a result of these limitations, the calculations expressing safe disposal concentrations contain an additional safety factor to allow for the deficit of information on this problem. Each of the NAS-NRC studies cited recommended that further research be conducted in the seven categories cited earlier. Because of the 1963 curtailment of marine discharge of radioactive waste, relatively little of this research has been carried out.

Another recommendation of importance concerns the necessity for monitoring and maintaining records of the amount and location of radioactive waste disposal operations. Both the Carrit and Isaacs studies also pointed out the need for periodic observation of the disposal sites in order to document the distribution of nuclear activity and its effects on the biota, and to provide an indication of whether or not the original assumptions made to determine allowable discharge rates are valid.[58,60] Isaacs and his associates recommended that the monitoring and observation program be conducted by an agency other than the AEC or its contractors.

To the writers' knowledge, only three sites used for disposal of containerized radioactive wastes have actually been resurveyed by the AEC (or with AEC funds). These are: (1) a site off the Farallon Islands near San Francisco;[61] (2) the aforementioned site at the Santa Cruz basin, some 70 miles west of Los Angeles;[60] (3) a site about 130 miles east-southeast off Cape May, New Jersey.[13,58,62] For the two West Coast sites, the results of beta-gamma counting of sediment samples indicated that no radioactivity above natural background levels was present. Similar counts for the site off Cape May, however, produced indications in 1961 of possible leakage of radioactive materials from the containers.[13,62] Despite these findings, no further investigations of the disposal areas have been reported. The need for, and the problems associated with, ongoing environmental monitoring of marine waste disposal operations are discussed in more detail in Chapter IV.

Military Explosives and Chemical Warfare Agents

Surplus or obsolete explosives and chemical and biological warfare agents (CBW) have been disposed of at sea for many years. Summaries by Busby, Hunt, and Rainnie and by Kurak indicate the extent of recent oceanic disposal operations including the Navy's CHASE program (discussed in Chapter IV).[63,64]

Although the environmental effects of explosives disposed in the ocean are probably quite limited, they certainly pose hazards to man and his equipment. Busby and co-workers discussed the hazards that explosive wastes present to operations conducted with research submarines and indicated that, although most of the explosive disposal sites (Figures 1-3) are situated in at least 6,000 feet of water, large amounts of explosive ordnance have come to rest in the shallow waters of the Continental Shelf as a result of combat operations.[63]

CBW agents, on the other hand, because of their inherent toxicity, constitute potential hazards of considerably greater significance. Unfortunately, the nature and scope of these hazards are not well understood. In a recent study by a special panel of the National Academy of Sciences to consider proposed marine disposal of CBW agents by the Army, it was noted that while

> "... various chemical warfare agents have been repeatedly disposed of in the oceans by the United States and other nations... we have no information regarding possible deleterious effects of these operations on the ecosphere of the seas."[65]

According to Boffey and to Ludwigson, on three occasions in the past the U.S. Army had disposed of chemical weapons in the ocean, but had made no effort to determine whether or not there would be harmful effects on the environment.[66,67] These reported instances do not include a 1958 disposal operation in which the Army disposed of 8,000 tons of mustard and lewisite gas by loading it aboard a surplus vessel, towing her to sea, and scuttling her.[64]

The CHASE disposal operation represents a decided improvement over the previous method of barging explosive wastes to sea, but its use for disposal of CBW agents is questionable because of the possibility that detonations of the associated explosives in the cargo after sinking would liberate the CBW material. In this regard, at least two of the vessels sunk in the CHASE program have not detonated according to plan.[67,68]

The National Academy of Sciences' special panel on disposal methods for CBW agents stated that certain CBW agents already embedded in concrete could be disposed of in the sea without serious environmental effects, but specified that this was accepted as a last resort solution in the event land disposal would pose unnecessary hazards to disposal personnel.[65] The panel also recommended that in the future the Army should assume that all chemical weapons will require eventual disposal and should, consequently, build disposal facilities that will not require dumping at sea.

General Considerations. Our present understanding of the short- and long-term responses of the more important marine food chain organisms to various types of waste is extremely limited. For example, wastes may have a detrimental effect through alterations in the natural environmental conditions (i.e., temperature, pH, etc.) or through physiological and other changes resulting from the addition of the wastes, or through both. Thus, in determining the toxic effects of wastes, it is important to consider environmental, physiological, and accumulative effects. Not only are marine organisms directly affected by wastes, but also indirectly through their interaction with other forms of organisms which comprise their food, competition, and predators. The situation is further complicated by the fact that different species and different developmental or life stages of the same species may vary widely in sensitivity or tolerance to different wastes. Thus, unfavorable conditions which may be tolerable for long periods by adults may be entirely unfavorable for spawning, and thus possibly endanger survival of the species.

From the foregoing, it can be seen that a great deal of work remains to be done in order to establish both the short- and long-term environmental effects of various classes of wastes in the marine ecosystem. Laboratory tests on specific organisms, both on a short- and long-term basis, are required in order to establish safe discharge rates of the various wastes. The results of these tests must then be tested in the field to determine their adequacy for protection of marine life in the disposal area.

The latter requirement will involve extensive research, both on the organisms themselves and on effective sampling and bioassay techniques. For example, Hood and co-workers have shown that field sampling utilizing standard oceanographic techniques was inadequate for the purpose of obtaining test organisms in the Gulf of Mexico.[15-19] Furthermore, samples collected periodically on this basis reflect only the conditions at the time that they were collected, and there was no way to determine if the organisms were endemic to the disposal area or migratory in nature. Similarly, there is no way to determine whether or not the wastes are responsible for more subtle sublethal effects on the biota as the waste field moves out of the original area under the influence of ocean currents.

PRINCIPAL AREAS OF ENVIRONMENTAL RESEARCH NEEDS

Substantial research efforts related to the environmental effects of waste in the sea are required in three major areas to insure that the ocean environment is not damaged by discharges of waste and that the pollution problems that currently exist in most major U.S. rives, lakes, and estuaries are avoided. These three areas are: development of baseline environmental data, laboratory studies of waste toxicity, and studies of the fate of wastes in the environment and its effects on the biota.

Baseline Environmental Data

In order to properly evaluate the effects of introducing any given foreign substance into the marine environment, it is essential to have an adequate understanding of the various natural fluctuations of the biota and water mass characteristics that are normal for the area in question. Without such an understanding, it is impossible to distinguish between normal variations and those resulting from the presence of the pollutant.

Baseline studies carried out prior to discharging wastes are the most effective means of providing reference data for use as a standard in measuring the effects of introduction of wastes. For an existing discharge, a control study area is set up in the general vicinity of the disposal operation but far enough removed so that it is not affected by the discharged material. In either case, a broad-spectrum study program is required. Physical and chemical studies of the control area serve to identify the natural processes responsible for the observed distributions of oceanographic properties, such as temperature, salinity, etc. Biological studies concentrate on both the quantity and quality of the biota, as well as the natural diversity of the fauna in the area.

Laboratory Studies of Waste Toxicity

The bulk of the toxicity test programs carried out to date on the various wastes being discharged at sea are discussed in Appendix D; they are limited both in scope and number. It is sometimes overlooked in establishing concentration limits based upon deaths of natural organisms that we don't want sick ones either. Substantial additional work is required not only on acute toxicity, but on chronic or sublethal toxicity as well, particularly for industrial wastes.

Nearly all toxicity bioassay experiments performed to date have been acute toxicities (TLM_{50}) which are only 96 hours in duration. Little has been done to observe the survival, reproduction, and behavior of successive generations to determine chronic toxicity levels of various wastes. Data resulting from some acute tests indicate although test animals survived certain concentrations, there was little or no reproductive capability in the first or second generation.

Because of the diversity of the marine fauna and the wide variety in types of wastes disposed at sea, short-cut methods are needed for determining the toxic effects of wastes both on a short- and long-term basis. For example, at the National Marine Water Quality Laboratory in Kingston, Rhode Island, toxicity studies have been centered around those organisms which comprise the largest percentage of the biomass in the marine environment. Another shortcut used at this laboratory is to determine which of the abundant organisms is most sensitive to each particular waste. These organisms are then used in tests to determine the long-term effects of the wastes.

Another important item for research is the development of standard test procedures which can easily be performed without expensive or elaborate instrumentation or highly trained personnel. The Marine Water Quality Laboratory has developed a bioassay technique that uses brine shrimp (Artemia) whose eggs are easily obtainable throughout the country. To further standardize these tests, sea-salts now on the market in convenient packages are recommended for the preparation of artificial seawater.

Research in toxicity effects on the marine environment resulting from barge disposal is nonexistent and urgently needed. Results of investigations around submarine outfalls in 400 feet of water or less over the past 20 years cannot be extrapolated to the much deeper truly oceanic conditions. Nevertheless, the data from the outfall studies provide useful guidance.

Fate of Wastes and Effects on the Biota

Understanding the fate of the waste after discharge requires an understanding of how the waste physically mixes and disperses in the sea, how the waste degrades chemically and biologically, and what components of the waste tend to concentrate either in the bottom sediments or in various plants and animals in the food chain.

Waste Dispersion. At present, the understanding of how wastes mix and disperse after discharge at sea is limited; generalized theoretical models are too imprecise to allow effective prediction for a specific disposal situation. Environmental studies are required to verify predictive models. Present disposal operations afford excellent opportunities for conducting important full-scale, at-sea experiments on mixing.

Improved sampling methods and equipment should be developed in order to obtain the necessary synoptic data to verify mixing models at all depths in the sea.

Because of the irregular frequency of many discharge operations, and the high costs of ship time for monitoring programs, research is also required to determine the most desirable spatial and temporal at-sea sampling patterns for various types of discharge operations.

Effects on the Biota. The research studies cited in earlier sections of this chapter constitute the bulk of the work on biologic response to barge-discharged wastes carried out to date. Although this work is extremely valuable, the fact remains that it merely scratches the surface of the problem. It is not an exaggeration to state that the environmental effects of past and present discharges are , with essentially no exceptions, not even qualitatively known, let alone measured. It follows that a major research effort in this area is essential.

POSSIBLE BENEFICIAL USES OF SOLID WASTES IN THE MARINE ENVIRONMENT

Although there are severe problems caused by tug and barge disposal of some classes of wastes, a large portion of solid wastes could be disposed of at sea so as to derive benefit. The greatest potential appears to lie in providing artificial habitats for fish.

The coastal zone of the United States is a relatively narrow strip of land bordering our coasts (and the Great Lakes) that contains nearly half of the Nation's population. As our economy and population expand, the coastal zone is becoming increasingly subject to conflicting uses of the relatively limited marine resources available. These uses include fisheries, recreation, fossil fuel and mineral resources development, marine transportation, real estate development, and the disposal of a variety of solid and liquid wastes. Few of these uses are compatible, let alone complimentary. The question of beneficial uses was investigated in the present survey, and results indicate that the only volumetrically significant beneficial use of solid waste in the marine environment is in the construction of artificial reefs for fish habitats. In addition, some suggestions have been made for using selected solid wastes for the construction of breakwaters or islands.

According to current estimates, 82 million persons (12 years of age or older) reside in the marine coastal zone of 23 States.[69] This population is forecast to increase by 17 percent to 96 million by 1980. However, the total number of ocean-oriented recreation "occasions" such as sportfishing, boating, swimming, and surfing are forecast to increase from 1.8 billion in 1965 to 2.4 billion in 1980, a 30 percent increase. Total expenditures associated with these activities are expected to nearly double from $13 billion to $23.6 billion over the same period.

Artificial Habitats for Fish

At present, there are some 104 artificial habitats or reefs along the U.S. coasts (Figures 1 to 3). Most of these are experimental in character and have been established either by research scientists or local sportfishing interests. Typically, they are relatively small features made up of a variety of solid waste materials including cars, tires, etc., often placed near wrecked vessels. A discussion of various aspects of the potential for large-scale use of solid waste for construction of such artificial habitats follows.

Fishing Pressure. As the number of sport fishermen in the United States continues to grow at the rate of ten to fifteen percent annually, it is evident that the fish population that attracts these enthusiasts cannot remain static. According to Winslow and

Bigler in 1965, at least 40 percent of the 80-odd million* coastal zone population participated in sportfishing from the shore and small craft in U.S. coastal waters.[69] The threat of widespread overfishing is significant. In 1965, sportfishing in coastal waters represented a significant fraction of the $108 billion water-oriented recreational industry. Some areas are already heavily overfished. For example, the sheepshead and weakfish have nearly disappeared from the waters off New York and New Jersey.[70] Similarly, populations of black seabass, sheepshead, abalone, and lobster have been seriously reduced as the result of increased fishing pressures off the Southern California coast. It may be that artificial habitats will increase fisheries resources so as to minimize or reverse the effects of overfishing.

Lack of Natural Habitat. Most of the continental shelf within reach of sport fishermen and skin divers operating from small craft is an unproductive, flat, lifeless, sandy desert with very few relief features. Sport and commercial fishermen have known for years that naturally-occurring banks, pinnacles, and hills as well as shipwrecks on an otherwise featureless sea floor attract a variety of fish. These areas of high relief, whether natural or artificial, furnish a firm substrate for the encrustration of organisms, such as barnacles, mussels, and coral, and also provide the necessary protection, food, and spawning areas for fin fish. There is substantial evidence that in nearshore areas where junked cars and rubble have been dumped by man fishing has improved.[26]

Current Status

Recent studies conducted by the California Department of Fish and Game and the Bureau of Sport Fisheries and Wildlife's Sandy Hook Marine Laboratory have shown that properly constructed habitats are a very effective means in congregating the available fish from a given area.[26,71] It has been postulated that the artificial habitats constructed with solid waste serve to increase the populations of other migratory fish by providing additional spawning sites for adults and protection and food for the juveniles.[71]

At the present time, because of the ease in handling, availability, long-life, and low cost, automotive tires are the most attractive material for constructing artificial reefs. Research at the Sandy Hook Marine Laboratory has shown that of several materials tested (wood, glass, concrete, metal, etc.) in the environment, rubber was found to be the most desirable substrate for colonization by the majority of invertebrate organisms in the area.[71] During 1969, over 30,000 tires were implanted on three different experimental reefs. Each reef is being inspected by biologist-divers to assess the effectiveness of the tires in increasing the productivity of the area and to inspect the development of new fish around the habitat. Support for this program has been supplied by the Bureau of Solid Wastes Management. Several types of artificial habitats have been constructed with such wastes as car bodies, tires, and rubble, and the various marine life have been attracted to them (Figures 15 to 20).

A report describing the characteristics of the various existing artificial reefs off the Atlantic and Gulf coasts is currently being prepared by the Bureau of Sport Fisheries and Wildlife's Sandy Hook Marine Laboratory.

It has been suggested that baled refuse would provide both food and habitat as a means of enhancing the production of the environment. The Sandy Hook Marine Laboratory has been carrying on an experimental program to monitor the effects observed in placing baled refuse in shallow water (Figure 20). The initial experiment was inconclusive because of storm damage, but further observations of various types of bales are scheduled.

Availability of Potentially Suitable Solid Waste Material

With regard to the availability of wastes suitable for use in construction of artificial habitats, of the 110 billion tons of solid waste generated annually in the United States, it is estimated that 10 million tons of construction debris, 9 million junked cars, and 100 million old vehicular tires are disposed of annually.[72,73] Although a portion of the cars and tires are reduced and converted into usable scrap, it is likely that a significant fraction of the scrap cars, tires, and debris produced in the populous coastal zone must be disposed of. For example, 20,000 abandoned cars

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* This number is significantly higher than the popular often-cited figure of eight million salt water fishermen, but appears to be reasonable and consistent with a national percentage of fishermen compared to total population. Further, these figures do not include the additional population that also participated in sportfishing aboard chartered fishing vessels.

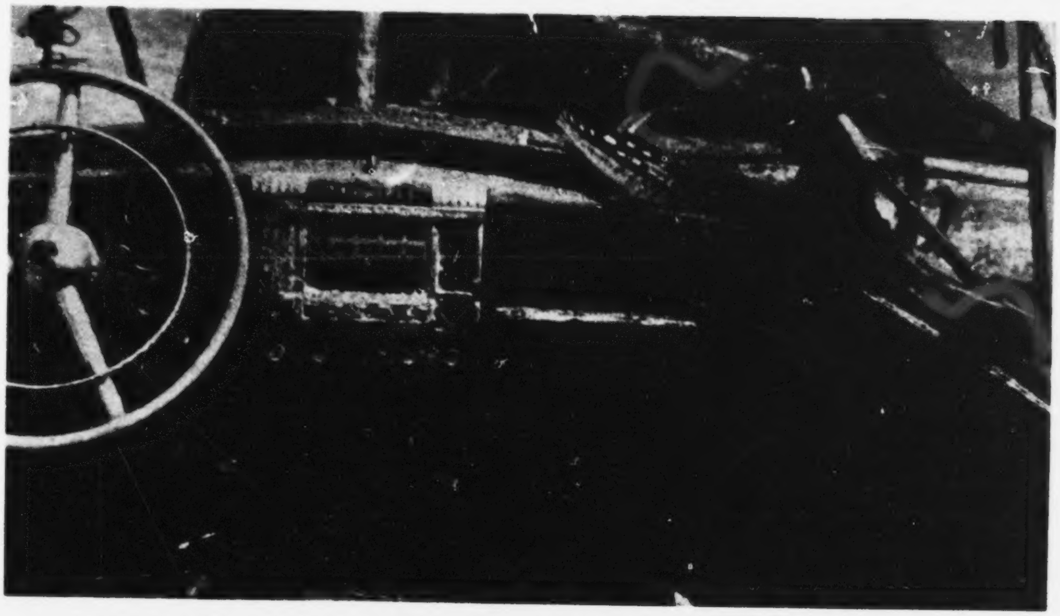

FIGURE 15. Kelp bass and sheephead investigating a recently dropped automobile body in a man-made fishing reef off California (California Department of Fish and Game photograph by Charles H. Turner, Marine Resources).

FIGURE 16. Remains of an automobile body used to construct an artificial fishing reef after four years of submergence. Photograph by Charles H. Turner, Marine Resources, California Department of Fish and Game.

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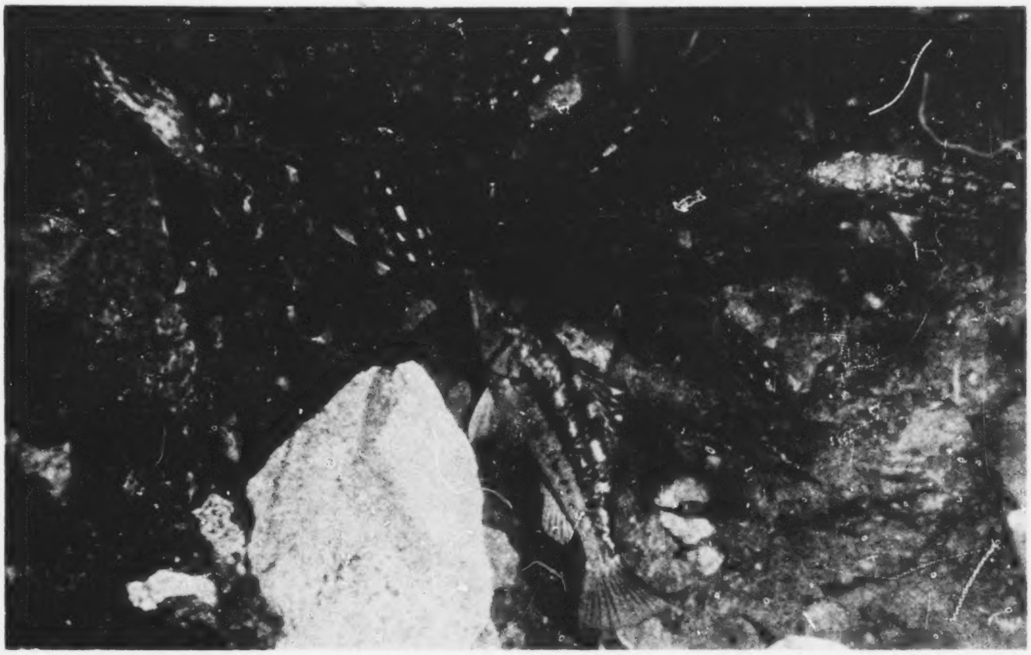

FIGURE 17. Kelp bass and black perch attracted to recently dumped quarry rock. (Photograph by Charles H. Turner, Marine Resources, California Department of Fish and Game.)

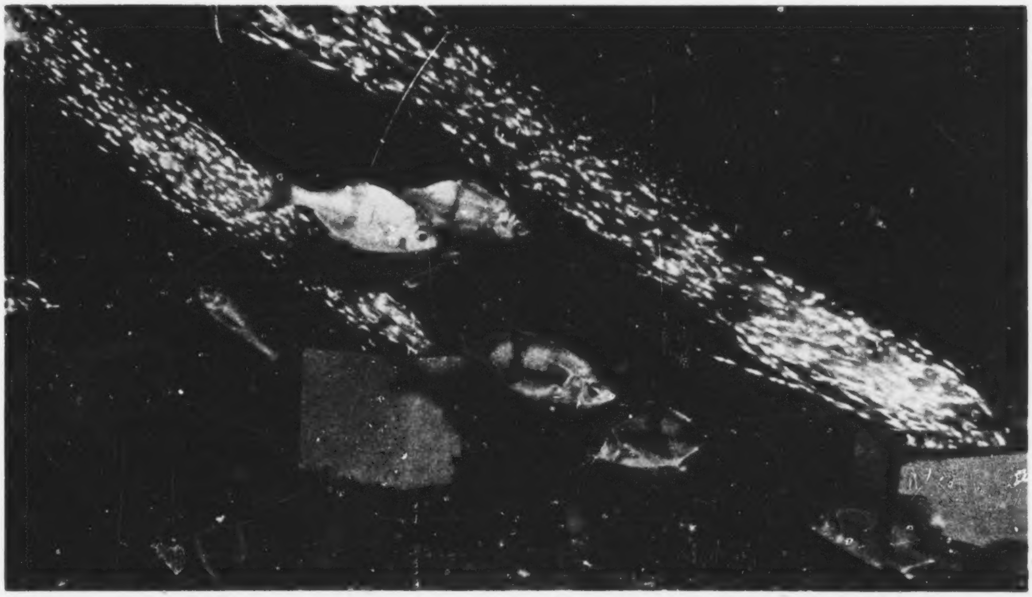

FIGURE 18. Experimental reef designed to test the effectiveness of utilizing artificial algae (plastic strips) as a means of allowing full utilization of the water column by the fish. (Photograph by Charles H. Turner, Marine Resources, California Department of Fish and Game.)

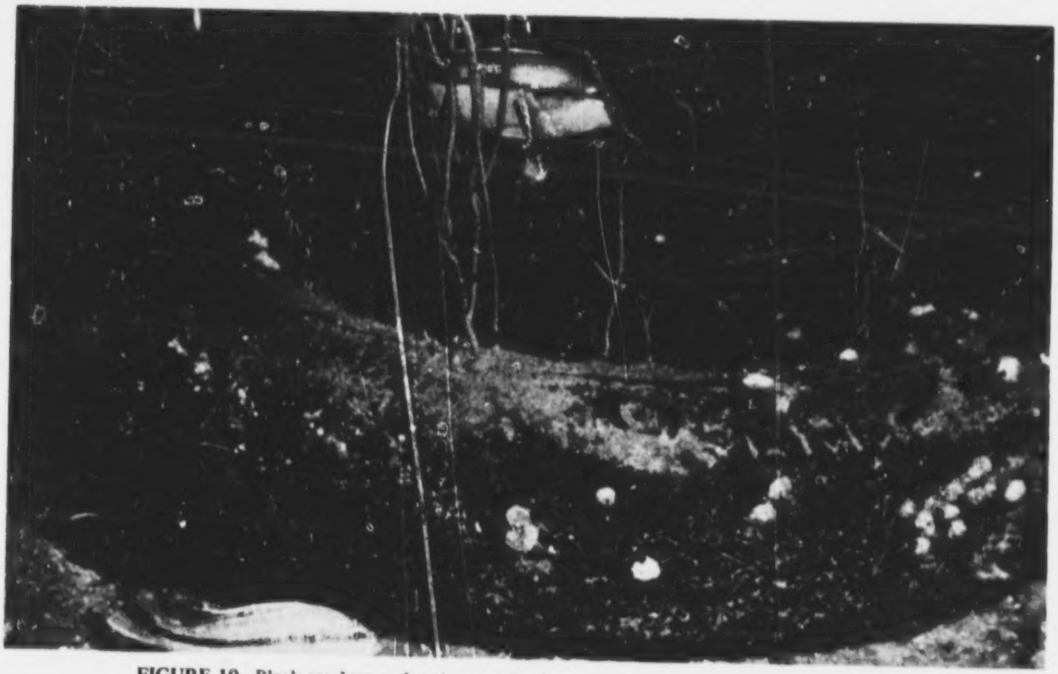

FIGURE 19. Black sea bass and various marine invertebrates attracted to a discarded tire in 70 feet of water off Jacksonville, Florida. Photograph by Tony Chess. Supplied by Richard Stone, U.S. Bureau of Sport Fisheries and Wildlife.)

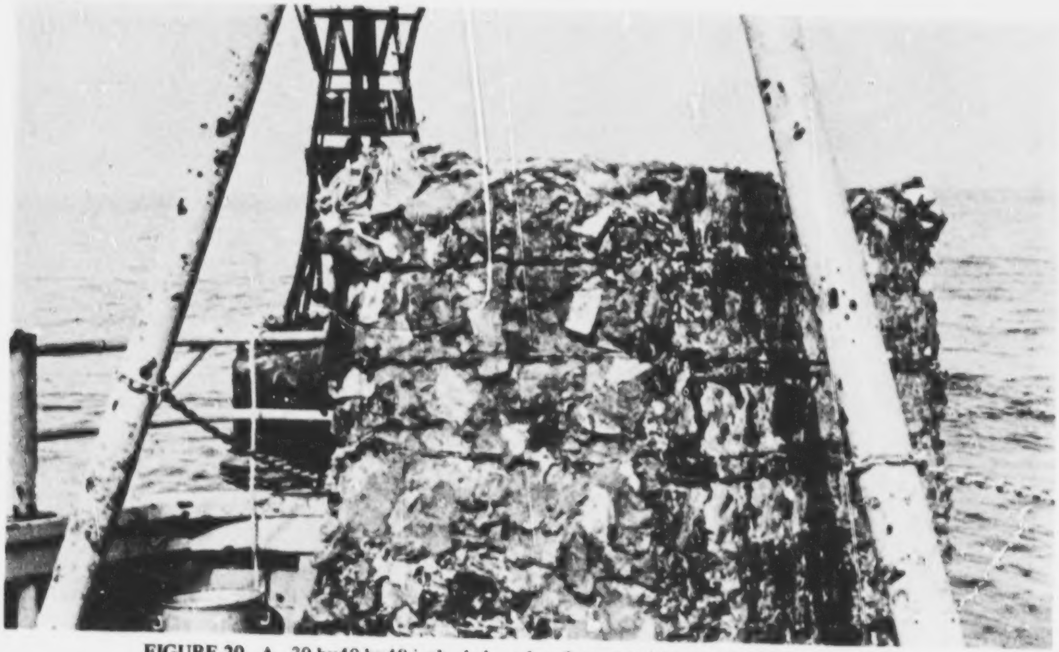

FIGURE 20. A 30-by40-by48-inch bale of refuse weighing about one ton before implantation for observation in 45 feet of water off Sandy Hook, New Jersey. (Photograph courtesy of Jack Balsamo, Moran Towing Corporation.)

were reported by the city of Philadelphia and over 36,000 by the city of New York in 1968.[74] Sittig reported that 5,000 tons per day of construction demolition waste are deposited in sanitary landfills operated by Los Angeles County.[75] During the present survey, it was determined that New York City annually disposes of over 500,000 tons of demolition and construction debris in landfills and ocean disposal sites.

Estimated Costs

Although evidence gathered over the past 10 years shows that artificial habitats constructed of solid wastes substantially increase sport fishing productivity in local sites, no large-scale program has been undertaken. In examining some of the reasons, it is seen that the cost of preparation and emplacement of the junked cars was relatively high and that the metal was corroded in 3 to 5 years with resulting loss of the reef (see Figure 16). Estimates made by researchers at the Sandy Hook Marine Laboratory indicated that the cars cost from $70 to $100 each because of the cost of handling, barging, and implanting (Figure 21). Although the use of concrete culvert was favorable as a habitat, it too was considered too expensive and heavy to be feasible for reef construction.

Over the last three or four years, experimental work with rubber tires showed these cost less than a

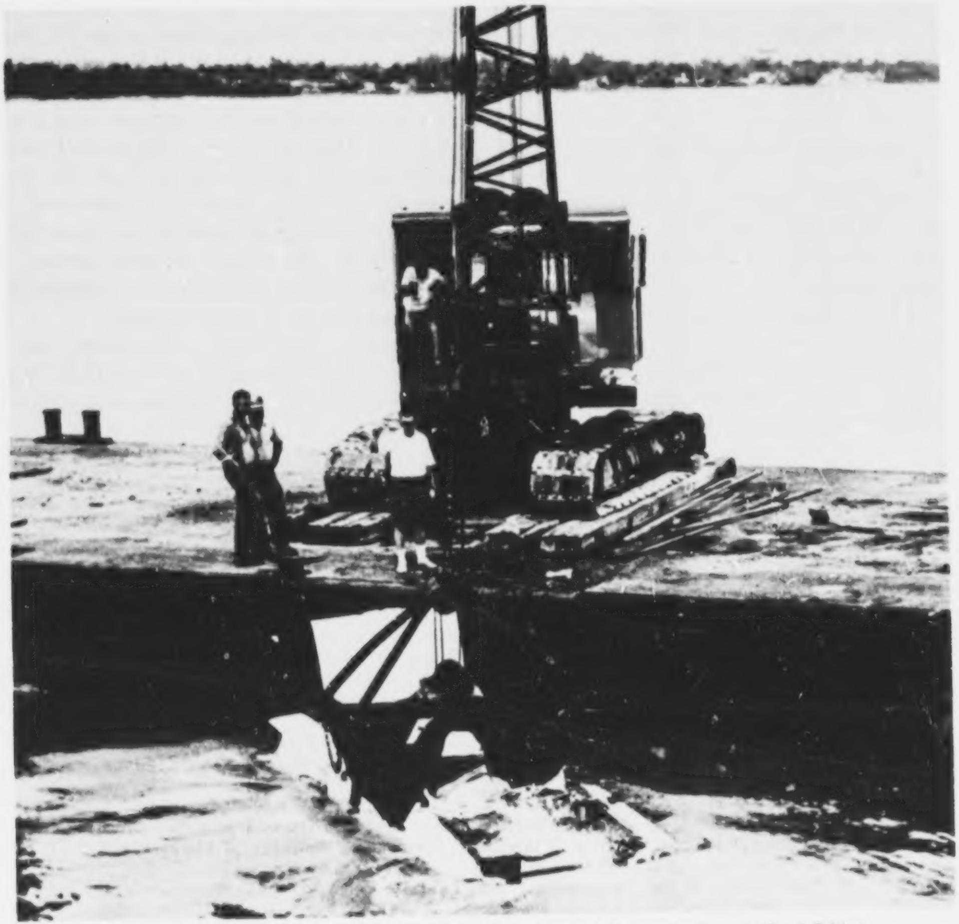

FIGURE 21. Method used to implant junked cars for establishment of an artificial fishing reef in shallow water off the New Jersey coast. (Photograph courtesy of Richard Stone, Sandy Hook Marine Laboratory.)

dollar each, and could be assembled and implanted by local fishing and diving clubs. One method uses four to seven tires joined with steel rodding and weighted with concrete ballast. These units become useful fish habitats after one to two years, when they are thoroughly encrusted with marine growth.

Although it is possible to construct effective artificial fishing reefs from certain types of solid wastes, present practice favors disposal in landfills or recycling as scrap steel. It is conceivable, however, that in only a few years, land values and the volume of solid wastes will make extensive reef construction attractive. In this regard, the controlled building of these reefs in the marine environment for the benefit of sport fishermen would be analogous to the onshore reclamation of canyons and undesirable parcels of land utilizing sanitary landfill techniques for the purpose of creating parks, golf courses, etc. In any event, there is an immediate and continuing need for research and development related to this area.

Other Beneficial Uses of Solid Wastes

Other potential beneficial uses of solid waste materials in the marine environment include its use as a building material in artificial islands, surfing reefs, and floating breakwaters.

Surfing Reefs. Grigg has proposed that demolition rubble be used for constructing artificial surfing reefs off the California coast to supplement the natural reef or shoal areas now heavily congested with an estimated 600,000 surfers.[76] With proper construction, he envisions that these reefs could also serve sport fishermen and skin divers. Grigg estimates that a prototype surfing reef constructed of quarry stone off the coast of Southern California would cost about $150,000. Compared to other environmental improvement projects undertaken by the Corps of Engineers, this figure does not appear excessive. For example, $330,000 was spent on sand dredging last year for beach replenishment in the area of Newport Beach, California.[76] Grigg points out that at present there are no definitive studies to guide the design and construction of multiple-use artificial reefs close to shore, and that further research should be conducted to evaluate their potential.

Floating Breakwaters. Another concept noted during the survey was the proposed use of scrap tires for the construction of a moored, floating offshore breakwater to attenuate wave action.[77] This structure would consist of large truck tires joined to form flexible floating barrier. Related experimental work has been carried out by Uniroyal using a series of baffles to break up the orbital motion of waves, thus dissipating the energy offshore. Costs for the materials for a floating breakwater constructed of used tires are estimated at $600 per 100 lineal feet. Costs for anchors and related mooring tackle, and for installation and maintenance will probably be many times the cost of the basic materials.

Additional research on this concept may find a way to successfully combine the surfing/fishing reef with the breakwater and use both construction rubble and tires.

REFERENCES

1. BUELOW, R. W. Ocean disposal of waste material. *In* Transactions; National Symposium on Ocean Sciences and Engineering of the Atlantic Shelf, Philadelphia, Mar. 19-20, 1968. Marine Technology Society. p. 311-337.
2. HUME, N. B., and W. F., GARBER. Marine disposal of digested screened wastewater solids. *In* J. P. MAROTO, and F. JOSA, *chairmen*. Advances in water pollution research. v. 3. Washington, Water Pollution Control Federation, 1967. p. 243-262.
3. CARLISLE, J. G., JR. Results of a six-year study in an area of heavy waste discharge, Santa Monica Bay, California. *California Fish and Game*, 55(1):26-46, Jan. 1969.
4. NORTH, W. J. Ecology of the rocky nearshore environment in Southern California and possible influences of discharged wastes. *Journal of Air & Water Pollution*, 7(6/7):721-736, Aug. 1963.
5. SAILA, S. B., T. T. PALGAR, and B. A. ROGERS. Results of studies related to dredged sediment dumping in Rhode Island Sound. *In* Proceedings of the Annual North Eastern Regional Antipollution Conference, University of Rhode Island, Kingston, July 22-24, 1968. p. 71-80.
6. Panel reports of the Commission of Marine Science, Engineering and Resources. v. 1. Science and environment. Washington, U.S. Government Printing Office, 1969. 364 p.
7. BIGGS, R. B. Environmental effects of overboard spoil disposal. *Journal of the Sanitary Engineering Division*, Proc. ASCE, 94(SA3):477-487, June 1968.

8. GROSS, M. G. New York City–a major source of marine sediment. Marine Sciences Research Center Technical Report No. 2. Stony Brook, State University of New York, Sept. 1969. 24 p.
9. WUESTEFELD, R. H. Waste disposal in the coastal waters of New York harbor. Unpublished data. New York, U.S. Army Corps of Engineers, 1968. 11 p.
10. REDFIELD, A. C., and L. A. WALFORD. A study of the disposal of chemical waste at sea; report of the Committee for Investigation of Waste Disposal. National Research Council Publication No. 201. Washington, National Academy of Sciences, 1951. 49 p.
11. KETCHUM, B. H., and W. L. FORD. Rate of dispersion in the wake of a barge at sea. *Transactions of the American Geophysical Union*, 33(5):680-684, Oct. 1952.
12. KETCHUM, B. H., C. S. YENTSCH, and N. CORWIN. Some studies of the disposal of iron wastes at sea. Reference 58-7. Woods Hole Oceanographic Institution, 1958. 17 p. (Unpublished manuscript.)
13. SCHUYLER, S., and G. HEIMERDINGER. Continental margin data collection pilot project; a Division of Research and Development open-file report (CT-02-69-45). [Cincinnati] U.S. Department of Health, Education, and Welfare, 1970. [81 p.] [Restricted distribution.]
14. KETCHUM, B. H. Marine pollution problems in the North Atlantic area. *In* C. M. TARZWELL, *ed.* Biological problems in water pollution. Transactions of the Second Seminar on Biological Problems in Water Pollution, Cincinnati, Apr. 20-24, 1959. Robert A. Taft Sanitary Engineering Center, 1960. p. 212-217.
15. HOOD, D. W., and W. ABBOTT. A study of the disposal of paper mill wastes at sea. Unpublished data [Project 112, Reference 55-42T]. College Station, Texas A&M Research Foundation, 1955. 30 p.
16. HOOD, D. W. The disposal of chlorinated hydrocarbons at sea. Unpublished data [Project 69, Reference 54-47T]. College Station, Texas A&M Research Foundation, 1954. 33 p.
17. HOOD, D. W., and B. STEVENSON. The disposal of chlorinated hydrocarbons at sea. Unpublished data [Project 69, Reference 55-23T]. College Station, Texas A&M Research Foundation, 1955. 40 p.
18. HOOD, D. W., B. STEVENSON, and J. B. SMITH. The disposal of chlorinated hydrocarbons and other chemical wastes at sea. Unpublished data [Project 69, References 57-20T]. College Station. Texas A&M Research Foundation, 1957. 30 p.
19. HOOD, D. W., B. STEVENSON, and L. M. JEFFREY. Deep sea disposal of industrial wastes. *Industrial and Engineering Chemistry*, 50(6):885-888, June 1958.
20. OCEANONICS, INC. Toxicity study for General Aniline and Film Corporation. Unpublished data. Houston, [1967].
21. OCEANONICS, INC. Report Phase II waste disposal study for the Lubrizal Corporation. Unpublished data. Houston, [1967].
22. MACSMITH, W., JR. Offshore disposal of industrial waste. Presented at 42d Annual Conference, Water Pollution Control Federation, Dallas, Oct. 5-10, 1969. 8 p.
23. STEIN, J. E. Observations on the disposal of sodium sludge in the Gulf of Mexico. Unpublished data [Project 147, Reference 56-36T]. College Station, Texas A&M Research Foundation, 1956. 7 p.
24. WALLER, R. Deep sea disposal of drummed wastes. La Porte, Texas, E. I. du Pont de Nemours and Company, Inc., 1968. 12 p. Unpublished manuscript.
25. TURNER, C. H., J. G. CARLISLE, JR., and E. E. EBERT. Offshore oil drilling, its effect upon the marine environment. Unpublished data. California State Department of Fish and Game, 1958. 3 p.
26. CARLISLE, J. G., JR., C. H. TURNER, and E. E. EBERT. Artificial habitat in the marine environment. Resources Agency of California Fish Bulletin 124. Sacramento, California Department of Fish and Game, 1964. 93 p.
27. THUMS LONG BEACH COMPANY. Disposal of drilling waste in the San Pedro Channel. Unpublished data, 1966. 6 p.
28. ZOBELL, C. E. The occurrence, effects, and fate of oil polluting the sea. *Journal of Air & Water Pollution*, 7(2/3):173-197, May 1963.
29. MOSS, J. E. Character and control of sea pollution by oil. Washington, American Petroleum Institute, 1963. 122 p.
30. HOLCOMB, R. W. Oil in the ecosystem. *Science*, 166:204-206, Oct. 10, 1969.
31. BLUMER, M. Oil pollution of the ocean. *In* Water pollution–1969; hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works, U.S. Senate, 91st Cong., 1st sess., S.7 and S.544. pt. 4. Washington, U.S. Government Printing Office, 1969. p. 1485-1489.
32. BUELOW, R. W., B. H. PRINGLE, and J. L. VERBER. Preliminary investigation of waste or installation disposal in the New York Bight. Unpublished data. Narragansett, R. I., Northeast Marine Health Sciences Laboratory, Jan. 1968. 33 p.

33. BUELOW, R. W., B. H. PRINGLE, and J. L. VERBER. Preliminary investigation of sewage sludge dumping off Delaware Bay. Unpublished data. Narragansett, R.I., Northeast Marine Health Sciences Laboratory, Jan. 1968. 20 p.
34. VERBER, J. L., R. W. BUELOW, and B. H. PRINGLE. Ocean disposal of waste material–off Delaware Bay and New York Bight. *In* Proceedings; Second Mid-Atlantic Industrial Waste Conference, Drexel Institute of Technology, Nov. 18-20, 1968. Philadelphia, 1969. p. 127-153.
35. PEARSON, E. A. An investigation of the efficacy of submarine outfall disposal of sewage and sludge. State Water Pollution Control Board Publication No. 14. Sacramento, California State Water Pollution Control Board, 1956. 154 p.
36. RITTENBERG, S. C. Studies on coliform bacteria discharged from the Hyperion Outfall; final bacteriological report. Submitted to Hyperion Engineers, Inc., by University of Southern California, Aug. 29, 1956. 72 p.
37. GUNNERSON, C. G. Sewage disposal in Santa Monica Bay. *Transactions of the American Society of Civil Engineers*, 124:823-851, 1959.
38. BROOKS, N. H. Diffusion of sewage effluent in an ocean-current. *In* E. A. PEARSON, *ed.* Proceedings of the First International Conference on Waste Disposal in the Marine Environment, University of California, Berkeley, July 22-25, 1959. New York, Pergamon Press, 1960. p. 246-267.
39. GRIGG, R. W., and R. S. KIWALA. Some ecological effects of discharged wastes on marine life. *California Fish and Game*, 56(3):145-155, 1970.
40. Personal communication, J. L. VERBER, Northeast Health Science Laboratory, to R. P. BROWN, Dillingham Corporation, 1968.
41. BLACK, R. J. A preliminary report on the proposal plan to dump refuse at sea by the City of San Juan, Puerto Rico. Unpublished data. U.S. Public Health Service, Division of Environmental Engineering and Food Protection. Mar. 1963. 16 p.
42. FIRST, M. W. Systems analysis for shipborne municipal incineration. *In* L. W. LEFKE, *Comp.* Summaries of solid wastes research and training grants–1968. Public Health Service Publication No. 1596. Washington, U.S. Government Printing Office, 1968. p. 22.
43. OVIATT, C. A. The effects of incinerator residue on selected marine species. *In* Proceedings of the Annual North Eastern Regional Antipollution Conference, University of Rhode Island, Kingston, July 22-24, 1968. p. 108-110.
44. A progress report on studies to determine the effects of suspended solids on marine fishes, with special reference to the effects of finely divided incinerator residue on selected inshore species. Unpublished data. [Cambridge,] Harvard School of Public Health, Environmental Health Sciences Laboratory, 1968. 24 p.
45. DUNLEA, J. V., JR. Method of bulk rubbish disposal. U.S. Patent 3,330,088, July 11, 1967.
46. Dillingham investigating solid waste disposal at sea. *Seahorse*, 3(5):1, 1968.
47. BALBI, V. L. U.S. Patent application on refuse disposal system and apparatus. Daly City, Calif., 1966. 8 p.
48. SMITH, R. A. Deep sea refuse disposal. U.S. Patent 3,395,663, Aug. 6, 1968.
49. Everybody produces it; nobody wants it. *Seashore*, 3(8):6, 1969.
50. Where to dispose of our refuse? Some say in the sea. New England Marine Resources *Information 2*, June-July 1969. Narragansett, R.I., New England Marine Resources Information Program. 2 p.
51. SILVERMAN, L. Incineration of solid wastes at sea. *APWA Reporter*, 31:2, 4, July 1964.
52. Progress report–systems analysis for shipboard municipal incineration. Unpublished data, May 1, 1967-Apr. 30, 1968.
53. PC3B's job for Harvard's School of Public Health. *Ocean Science News*, 10(48):3, Nov. 29, 1968. (Abstract.)
54. METCALF AND EDDY/ENGINEERS. Report to the New York State Pure Waters Authority on rail-haul disposal of solids wastes for Westchester County, New York. Unpublished report. New York, Feb. 27, 1969.
55. Personal communication. C. G. GUNNERSON, Bureau of Solid Waste Management, to R. P. BROWN, Dillingham Corporation, 1969.
56. STONE, R. B. Summary cruise report R. V. Challenger. Unpublished data. Highlands, N. J., U.S. Bureau of Sport Fisheries and Wildlife, Sandy Hook Marine Laboratory, 1968. 3 p.
57. NATIONAL ACADEMY OF SCIENCES COMMITTEE ON EFFECTS OF ATOMIC RADIATION ON OCEANOGRAPHY AND FISHERIES. The effects of atomic radiation on oceanography and fisheries. National Research Council Publication 551. Washington, National Academy of Sciences–National Research Council, 1957. 137 p.
58. NATIONAL RESEARCH COUNCIL COMMITTEE ON OCEANOGRAPHY. Radioactive waste disposal into Atlantic and Gulf coastal waters; a report from a

working group of the Committee on Oceanography of the National Academy of Sciences–National Research Council. National Research Council Publication No. 655. Washington, National Academy of Sciences, 1959. 37 p.

59. NATIONAL ACADEMY OF SCIENCES COMMITTEE ON EFFECTS OF ATOMIC RADIATION ON OCEANOGRAPHY AND FISHERIES. Considerations of the disposal of radioactive wastes from nuclear–powered ships into the marine environment. National Research Council Publication 658. Washington, National Academy of Sciences–National Research Council, 1959. 52 p.
60. NATIONAL RESEARCH COUNCIL COMMITTEE ON OCEANOGRAPHY. Disposal of low-level radioactive waste into Pacific coastal waters. National Research Council Publication 985. Washington, National Academy of Sciences–National Research Council, 1962. 87 p.
61. PNEUMODYNAMICS CORPORATION, ADVANCED SYSTEMS DEVELOPMENT DIVISION. Technical report. Survey of radioactive waste disposal sites. TID-13665. Washington, U.S. Atomic Energy Commission, July 15, 1961.
62. U.S. COAST AND GEODETIC SURVEY. Sea disposal of low-level packaged radioactive waste. Unpublished data [Coast and Geodetic Survey Project 10,000-827]. 1961.
63. BUSBY, R. F., L. M. HUNT, and W. O. RAINNIE. Hazards of the deep. Pt. 2. Millions of tons of explosives comprise the greatest hazard to submersible operations. *Ocean Industry*, 3(8):32-39, Aug. 1968.
64. KURAK, S. Operation chase. *United States Naval Institute Proceedings*, 93(9):40-46, Sept. 1967.
65. BOFFEY, P. M. Academy changes army gas dump plan. *Science*, 165:45, July 4, 1969.
66. BOFFEY, P. M. CBW: Pressures for control build in Congress, international groups. *Science*, 164:1376-1378, June 20, 1969.
67. LUDWIGSON, J. O. Washington report–nerve gas. *Oceans*, 2(5/2/6):72-75, Nov.-Dec. 1969.
68. PHILIPS, R. H. View from the west coast–U.S. agencies among polluters. *National Fisherman*, p. 6-A, Oct. 1969.
69. WINSLOW, E., and A. B. BIGLER. A new perspective on recreational use of the ocean. *UnderSea Technology*, 10(7):51-55, July 1969.
70. STONE, R. B. Artificial reef study. Unpublished data. Highlands, N. J., U.S. Bureau of Sport Fisheries and Wildlife, Sandy Hook Marine Laboratory, 1968. 8 p.
71. WALFORD, L. A., *comp.* Atlantic marine game fish research. *In* Progress in sport fishery research, 1967. Resource Publication No. 64. Washington, U.S. Bureau of Sport Fisheries and Wildlife, 1968. p. 167-188.
72. BLACK, R. J., A. J. MUHICH, A. J. KLEE, H. L. HICKMAN, JR., and R. D. VAUGHAN. The national solid waste survey; an interim report. [Cincinnati,] U.S. Department of Health, Education, and Welfare, [1968]. 53 p.
73. AMERICAN CHEMICAL SOCIETY COMMITTEE ON CHEMISTRY AND PUBLIC AFFAIRS, SUBCOMMITTEE ON ENVIRONMENTAL IMPROVEMENT. Cleaning our environment; the chemical basis for action. Washington, American Chemical Society, 1969. 249 p.
74. Abandoned cars: a dilemma of our times. *Solid Wastes Management/Refuse Removal Journal*, 12(2):42-43, Dec. 1969.
75. SITTIG, M. Water pollution control and solid wastes disposal, 1969. Park Ridge, N.J., Noyes Data Corporation, 1969. 244 p.
76. GRIGG, R. Artificial reefs. *Surfer*, 9(6):48-49, Jan. 1969.
77. STITT, R. L. Introducing wave-maze (floating breakwater). Unpublished brochure. Temple City, Calif., 1967.

IV. MONITORING OF MARINE WASTE DISPOSAL OPERATIONS

Monitoring of waste disposal operations at sea may be subdivided into two major categories: regulatory monitoring and environmental monitoring. Regulatory monitoring is concerned primarily with operational matters while environmental monitoring deals with the interaction of the waste with the ocean environment.

REGULATORY MONITORING

The objective of regulatory or enforcement monitoring is to ensure that disposal operations are carried out in the designated area and in the manner specified in the authorizing permit or letter of no objection. As such, regulatory monitoring normally consists of: (1) record keeping by the waste producer and disposal operator for submission to a regulatory agency. These include monthly, quarterly, or annual summaries of disposal operations describing the type and amounts of waste discharged. In addition, towboat logs, fathograms and photography of the vessel's radar screens are also submitted. In essence, this is self-enforcement supported by documentary evidence proving compliance; (2) inspection or surveillance on site or in transit by vessels or aircraft of the regulatory agencies.

Current Status

On the basis of the survey results, the current status of monitoring marine waste disposal operations in the United States for regulatory purposes is as follows.

Record Keeping. Three separate types of record keeping (or documentary monitoring) practices were encountered during the survey. The first is that used in the New York and Norfolk areas where disposal operators are required by the Corps of Engineers to submit regular (monthly, quarterly, etc.) summary data regarding the type and amount of wastes discharged at sea.

Annual summaries of the operations are maintained and updated regularly by the Corps. Although similar data on disposal operations are obtained from disposal operations in the Philadelphia area, it is strictly on a cooperative basis, as that particular District Office of the Corps claims no jurisdiction over disposal operations beyond the 3-mile limit.

The second type of record keeping situation was found in the cities of San Francisco, Los Angeles, San Diego, Boston, and New Orleans. In this case, the submission of regular data on individual disposal operations is required by the regulatory agencies, but there is no evidence that the data are evaluated. As a consequence, the responsible regulatory agency in these cities is generally unable to provide an overall description of the disposal operations conducted under its jurisdiction.

The third type of practice is essentially one of no records; after initial approval of a disposal operation by the District Office of the Corps of Engineers, no additional records are required or maintained by the regulatory agencies. This situation holds for the Seattle, Charleston, Mobile, and Galveston districts so that, as a result, the present status or changes to the original waste disposal plans are unknown. In some cases, the Corps officials were unable to advise whether firms that had received permission 10 to 15 years ago were still disposing of wastes at sea in 1968. This is in contrast to dredge spoil disposal data, which are up-to-date in all District Offices of the Corps.

Inspection. New York City is the only major U.S. city in which marine waste disposal operations are subject to regular surveillance, while in transit to the disposal area. In order to ensure that barge operators disposing of sewage sludge, chemicals, dredge spoils, and construction and demolition debris have traveled

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the required distance to the disposal areas, surveillance is conducted by recording the times of departure and return; this is done by government vessels stationed in lower New York harbor. A similar situation exists in San Diego where staff members of the Regional Water Quality Control Board accompany each load of barreled industrial wastes to sea. In both cases, the frequency of disposal varies from one to four times per year. It is not known whether the regulatory agencies involved plan to maintain this thorough operational surveillance in the event of future increases in sea disposal of wastes.

Incidential surveillance from aircraft and patrol boats is sometimes conducted in California and Louisiana by State fisheries agencies during their normal activities.

In summary, the level of documentary monitoring of operational practices of sea disposal of wastes is inadequate for the number and scope of disposal operations (see Chapter II).

Environmental Monitoring

The objective of environmental monitoring with respect to marine disposal of wastes is to determine both the short- and long-term effects of a given disposal operation. The monitoring results are essential for establishing water quality criteria applicable to the disposal of wastes, for assessing trends and changes, and for the identifying problem areas that require the attention of cognizant research and regulatory agencies.

Environmental monitoring includes periodic field observation and sampling, supported by laboratory testing and analysis. The objectives of environmental monitoring require a much more complex and costly program than regulatory monitoring, and necessitate specialized personnel and equipment for both the at-sea phase and the shore-based laboratory facilities and staff.

In some cases, regulatory and environmental monitoring programs compliment each other in that water quality data obtained as a regulatory requirement by the disposal operator are of value to the environmental monitoring phase of the waste disposal operation. As both McKee and Gunnerson have shown, however, this has been the exception rather than the rule.[1,2]

Current Status. The present study has shown that ongoing monitoring of current waste disposal operations (at sea or in the laboratory) for assessing potential environmental effects is clearly insufficient. Even in the case of the Galveston District of the Corps of Engineers, which probably has the most stringent requirements for environmental studies to be carried out prior to disposal authorization, lack of Federal and State funds for environmental control monitoring programs the necessarily limits their capability to verify original study results.

The foregoing situation exists in spite of the fact that the critical need for environmental monitoring of waste disposal has been emphasized in most of the literature reviewed. In particular, see the reports of McKee, McKee and Wolf, Federal Water Pollution Control Administration, Stein and Denison, Commission on Marine Science, Engineering and Resources, Ketchum and Ford, MacSmith, Pearson, Carritt, Pritchard, and Isaacs, and their respective co-workers.[1,3-12]

Technical Aspects of Monitoring

The types of wastes being barged to sea are, in many cases, similar to those discharged into streams, rivers, bays, estuaries, and coastal waters. Accordingly, a monitoring program established to regulate and assess offshore disposal operations should be able to utilize at least some of the sampling, analytical, and evaluation information developed from estuaries or coastal waters.

Unfortunately, this extention of knowledge and technology has critical limits because of the logistic requirements for monitoring environmental effects of wastes discharged at sea. Few of the many wastes recognized as potentially toxic to freshwater organisms have been studied sufficiently to establish their maximum allowable concentrations under marine conditions.[4] Further, costs of a vessel, equipment, and personnel required to sample offshore disposal areas can run as high as $2,000 per day. As a result of these costs, the ultimate fate of the waste fields from disposal barges is unknown. Further, environmental and regulatory monitoring programs by their very nature require data collection on a long-term basis. Monitoring programs must be flexible. Initial sampling should determine which variables are significant and which, if any, can be safely ignored. Gaining even this level of understanding poses measurement problems that are not simple. For example, most of the effects of waste discharge operations observed in this study (Chapter III) were hampered by sampling problems which precluded a definitive analysis of the disposal operation.

Variability of Disposal Operations. Marine disposal operations vary in time, space, and materials. Monitoring the effects of wastes on the marine environment must be adjusted to frequencies of disposal, which can range from daily to weeks or even months. For example, waste acids and sewage sludge are disposed of daily in separate disposal areas located in the New York Bight. By contrast, toxic pesticide wastes are discharged some 100 miles at sea from New York at two-to-three-month intervals.

The problem of monitoring offshore disposal areas is further complicated by the fact that, with the exception of a few localities such as New York City, the wastes disposed at any one site commonly are dissimilar in character because they originate from more than one type of source. For instance, off Galveston, refinery wastes, pesticides, black liquor, and other industrial wastes are all disposed of in the same general area about 100 miles offshore. The frequency of disposal for a given operation in this area varies from weekly to once every two or three months. Thus, depending on the time that the area was sampled, the results could reflect the effects of all of the disposal operations or only that of the most recent discharge.

Another complicating factor is that the waste field developed either within the water column or on the bottom is not static, but is subject to progressive modifications by chemical, physical, and biological processes (*see* Chapter III). Under the influence of currents, the effects of a waste discharged in a given area will extend over a much broader area. The acute effects within the waste field will depend on the toxicity of the wastes, dilution, etc.

An important consideration here is that a drifting waste field, inadequately diluted, can pose a possible barrier to migration and free movement of marine biota. Spawning migrations may be blocked or diverted to unfavorable areas. Similarly, if the waste field entered a heavily spawned area and mixed with waters containing large concentrations of eggs and larvae, conditions unfavorable for survival could be produced. Depending on the scale of the phenomena, this could seriously cripple the survival of a given year-class for valuable coastal fisheries.

The present state of knowledge regarding mixing and diffusion of wastes at sea is generally inadequate for the purpose of establishing safe disposal areas, rates of disposals, and routine at-sea procedures for discharging the waste (i.e., depth of discharge, towing speed, etc.). As mentioned earlier, the investigations on the diffusion of wastes at sea have been restricted primarily to the surface layer. Studies by Hood and MacSmith on the disposal of chlorinated hydrocarbons and ammonia sulfate wastes, respectively, showed that diffusion and dilution of the submerged waste field is less rapid than that observed in the surface layer.[13,8] In order to verify existing models of diffusion and to develop new models, physical and chemical data are required that will allow for a description of the waste field three dimensionally in space over a sufficient period of time to observe changes that occur in the original waste concentration. Explicit to the collection of these data is the requirement for rapid sampling techniques that will allow for the development of a synoptic picture of the waste field.

Baseline Studies. Clarke and Neushul have pointed out that, in order to properly monitor and evaluate the effects of pollution and to establish effective control measures, researchers must develop the background knowledge required to be able to separate the natural fluctuations that occur in marine communities from those induced by the activities of man.[14] This requirement has been highlighted over the last few years with the occurrence of major oil spills from tankers and offshore drilling rigs. In both cases, the assessment of the adverse effects of the oil on the environment was hampered by the lack of ecological reference or base-line data which could be used as a standard from which changes caused by the oil could be measured. The same requirement applies equally to measuring and understanding the environmental effects of liquid and solid waste in the sea. To date, however, with the exception of research work carried out in connection with various U.S. fisheries* and on the possible effects of radioactive materials in the sea,[15,16] base-line ecological studies have not been made, primarily because of lack of funds.

The Commission on Marine Science, Engineering, and Resources has recognized this need for base line studies and their report recommends:

> "Specific representative sites should be selected for careful prolonged study to permit the accumu-

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* The California Cooperative Oceanic Fisheries Investigation (CCOFI) program has regularly sampled an extensive network of stations off the coast of California for plankton and physical oceanographic data since 1949.[19]

lation of basic knowledge essential for understanding the statics and dynamics of the coastal regime."[6]

Broad-gauge research programs that would provide valuable reference data have been proposed for the Gulf of Mexico by the Gulf Universities Research Corporation (GURC), and for the California nearshore waters by Clarke and Neushul.[17,14]

An engineer or scientist seeking marine data for assessing the natural environment in the region from the shoreline out to 50 to 100 miles is invariably surprised by the extremely limited amount of systematic environmental sampling in this geographic zone. In comparison to its potential use by man, far less is currently known about the nearshore and coastal zone than about the deep ocean. At present, the National Oceanographic Data Center is actively considering developing a Continental Shelf Data Bank to pull together all of the available data and literature regarding this region.[18]

Operational Aspects of Enforcement Monitoring

Delineation of Disposal Areas. From the information gathered during the survey, it is apparent that the determination of the physical limits of most marine disposal areas has been handled in an arbitrary fashion without any real consideration of the natural resources in the area or the constraints typically imposed by the very nature of the disposal operation. For example, most industrial or sewage sludges are discharged while underway at maximum speed; this provides the greatest initial dilution and minimizes acute effects. At the same time, the utilization of specific areas for successive discharges maximize chronic effects. Thus, in establishing disposal requirements for these wastes, such factors as total load, discharge rate, and towing speed should be considered in order to better define the outer limits of the disposal area. This is particularly important where the natural resources of an area are being harvested or have a future potential for exploitation.

In discussing discharge methods, Buelow points out that the size of the present sewage sludge disposal areas in the New York Bight and off Cape May, New Jersey, are incompatible with the methods of discharge.[20] Under the present system, a barge operator must discharge his load within 10 minutes at top speed, or turn around and make another run through the disposal area. This situation often leads to continuation of discharge outside the designated disposal area. Where shellfish sanitation is concerned, a mile or two discrepancy in the disposal of these wastes is important. In one discharge operation observed off Cape May, approximately two-thirds of the load was discharged outside of the prescribed area.

This problem arises from the lack of clearly marked disposal areas and the inadequate navigational aids used by the disposal operators. Most disposal operators in the New York Bight area utilize radar fixes on prominent land features to establish their position relative to the disposal area. For disposal areas further offshore, as in the Gulf of Mexico, either dead reckoning or celestial navigational methods are used. None of these methods provide highly accurate results and, thus, positioning for most of the disposal operations is quite crude.

Not all of the responsibility lies with the disposal operators, however, as in many cases the description of the disposal areas provided by regulatory agencies is so broad that it is impossible to define a given area. For example, such descriptions as "at least 20 miles from the coast," or "beyond the 400 fathom curve" require further delineation for identifying the area in which wastes are to be discharged and monitored.

Inspection of Disposal Operations. Inspection of disposal operations to ensure that operational requirements are being met is virtually nonexistent although examination of the operators' disposal records and observation of actual operations are prerequisites for staying ahead of potential problems.

A discussion of the problems of monitoring waste disposal operations for regulatory purposes raises more questions than answers. For example, how frequently should the disposal operations be inspected? What form of inspection is required—examination of vessel logs and fathograms, on-site visual inspection of the operations, or a combination of both? If a site inspection is to be made, what sampling and analytical procedures should be used?

All of these monitoring problems require adequate funds and personnel for research and development and for regulation. At the present time, examination of the records from current disposal operations is essentially perfunctory.

Regulatory monitoring of disposal operations raises questions regarding the procedures for proving violations. For example, what evidence is required to establish that a disposal operation was conducted in violation of requirements. Aerial photographs are one means of documenting such operations; in order to be effective, however, disposal operations must be monitored in this fashion on a regular basis.

Fathograms submitted by the disposal operator in most cases provide a means of verifying only that a tugboat traveled the required distance offshore; they do not necessarily provide information as to where specifically the operation took place. Besides, it is doubtful if anyone would submit such records if they were deliberately in violation of disposal procedures. What is needed is a tamper proof, automatic system that could be placed aboard a tugboat that would provide a data record adequate for determining just where and when the disposal operation took place.

Regulatory agencies are also faced with the task of ensuring that established water quality criteria are being met by the disposal operators. Information from the original producer of the wastes, verified by sampling of the barge loads, is required to provide data as to the character of the wasteloads and to establish if the required dilution of the wastes is actually achieved in the wake of the barge. Sampling must provide statistically sound data in order to adequately take into account the variability of both oceanographic factors and disposal procedures.

At the present time, however, the biggest drawbacks to proposed schemes for regulatory monitoring of marine waste disposal are the facts that: (1) the legal jurisdiction to regulate the disposal of wastes at sea to beyond the three-mile limit is not covered by Federal regulations; (2) there are no water quality criteria for ocean waters beyond the 3-mile limit. It is clear that, until such time that the power to regulate the disposal of wastes at sea is firmly established by Federal Law, the development of effective enforcement programs and the means for their implementation will not come to pass.

Research Needs Associated with Monitoring

Requirements for improved sampling to collect both research and regulatory data have been emphasized at various points in the foregoing sections of this chapter. These requirements and the research and development programs needed to fulfill them are discussed below.

Regulatory Monitoring Needs. In connection with regulatory monitoring, present inspection of disposal operations is inadequate. To correct this situation, an improvement in documentary monitoring, by means of an automatic tamper proof vessel log similar to that utilized by airlines and trucking firms, appears to be a partial solution to the problem. Such a system, consisting of readily available components, could be utilized in conjunction with a subsurface sonar beacon located on the bottom within a disposal area. One such system would work in the following manner:

The disposal area would be marked with a transducer-type "well-head" pinger or other similar sonar device with an operating range of approximately five miles. The pinger would respond to the vessel's fathometer output signal. A small receiver mounted on the towing vessel would pick up the pinger signal and feed it into the fathometer recorder. Thus, when in range of the bottom pinger marking the disposal area, a distinct trace would be visible on the towing vessel's fathometer record, indicating the vessel and barge are within the designated limits of the disposal area. In order to avoid engineering design problems, the operating frequency and repetition rate for such a pinger should be about 12KC and once per second, respectively. Average life of these beacons on the bottom is envisioned as between 12 to 18 months, which is within the state-of-the-art of present instrumentation.

In order to monitor the discharge rate of the disposal operation, a simple monitoring system could be incorporated in the barge pumping system. This monitor would record the pump speed (revolutions per minute) and the total elapsed time of the pumping operation.

A recording "pitlog" or a venturi-type hull speed sensor could be used to record hull speed through the water. Depending on the accuracy required, a study of surface currents in the area can be made and these data then used for interpolation to obtain true hull speed of the towing vessel over the bottom. All three of the foregoing monitoring records can be automatically stamped with data and time to provide correlation of towing speed, elapsed time in the disposal area, and the duration and rate of discharge of the waste.

Compliance with stated water quality criteria requires additional on-site sampling techniques. Along these lines, research is required to develop a simple, self-contained sampling device that can be towed at a given distance astern of the disposal barge. The purpose of this sampler would be to record only concentrations of the wastes which are above the specified limits of dilution. In this manner, a quantitative evaluation of the disposal operation could be made in terms of overall compliance with established water quality criteria. In some cases, it might be desirable to tag the wastes with a fluorescent dye or other tracer which can be easily measured with standard techniques.

The feasibility of utilizing remote sensors such as airborne fluorometers, radiation-thermometers, etc., for both regulatory and research monitoring purposes, holds exciting possibilities. Stoertz, Hemphill, and Markle recently have shown that, in extremely turbid waters in San Francisco Bay, an experimental airborne fluorometer was capable of sensing concentrations of Rhodamine WT dye in concentrations of less than five parts per billion.[21]

The use of airborne sensors for detecting and monitoring waste discharges at sea is timely in view of the recent plan outlined by the U.S. Coast Guard for a systematic air patrol to detect oil pollution in selected areas off the Pacific, Atlantic, and Gulf coasts.[22] Under this proposal, the Coast Guard would patrol some 2,000 miles of coast three times a week. The five-year cost of this program is expected to be about $29 million. With effective interagency cooperation, this program could be expanded to include monitoring of marine waste disposal operations.

Special regulatory and environmental sampling on a regular basis could best be accomplished by placing qualified observers aboard the disposal tug. Portable sampling systems, easily transported aboard the tug, could be constructed for this type of operation. In this way, no special vessel would be required, and the only cost involved would be for sampling equipment and personnel.

Environmental Monitoring Needs. Current techniques for monitoring environmental effects of wastes on the marine ecosystem are inadequate for both regulation and research. One monitoring method that looks promising for marine use is the collection of sedentary animals and plants that attach themselves to artificial test plates placed at various depths on a simple taut-wire buoy system. Such plates have been maintained in shallow coastal areas for nearly 20 years for the purpose of obtaining data on the productivity of the environment in relation to oceanographic changes.[4] It is envisioned that, because of the known ability of most attaching organisms to accumulate various components of waste (i.e., pesticides, heavy metals),[5] this method will be extremely useful to monitor the biological effects of pollution caused by the various waste disposal operations, both on a short- and long-term basis.* For example, plates could be changed at regular intervals and the organisms counted, volumetrically measured, or chemically assayed to provide a quantitative index of their relative abundance obtained. Comparison with samples obtained in control areas would allow for a realistic appraisal of the environmental effects of the wastes. Another favorable aspect of this monitoring method is that it would facilitate the collection of specimens for use in laboratory bioassay tests ashore.

The implementation of the foregoing method will require research to determine the best material for the test plates, the size and shape of the test plates, the optimum sampling interval and laboratory techniques, and the design and cost of the buoy system.

Research to develop methods and equipment adequate to sample the waste field produced by a disposal operation is required in order to obtain data for the verification of existing mixing models and to develop better models. The use of airborne sensors in conjunction with rapid surface and subsurface sampling techniques can provide the synoptic data that are required for this purpose. In the past, research efforts have been hampered because it has not been feasible to utilize several vessels to sample the waste field simultaneously. New research efforts should be directed towards the development of instruments (preferably with in-situ sensing capability) that can be attached at various depths to lightweight buoy systems for rapid deployment by a surface vessel. Thus, a single vessel could make several rapid traverses across the waste field to deploy the sensor systems for later retrieval at a predetermined time. In this manner, any number of almost synoptic cross sections of the waste field could be obtained at less than the expense of several sampling vessels.

Shipboard sampling systems are also required that will collect in the wake of the barge physical and chemical data from the waste field while the research vessel is underway. Every effort should be made to design this system so that it is as automated as possible in order to reduce the number of technical people involved in the collection and processing of the data.

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* The potential application of this method to pollution monitoring of nearshore and coastal waste disposal operations was suggested by Dr. Donald Mitchell of the Biome Company, Huntington Beach, California. Dr. Mitchell also serves as a member of the California State Water Quality Control Board, Region No. 8.

A point to note is that the development of instrumentation and techniques for the purpose of studying the mixing and diffusion of wastes at sea most certainly would provide a substantial part of the monitoring information that is required by regulatory agencies to ensure that disposal operations are conducted in the prescribed manner.

Because the data obtained from an effective environmental and regulatory monitoring program have the potential for multi-use by many Federal research and regulatory agencies, it is logical to suggest that the cost of the research required to develop these capabilities also be shared on an interagency basis. For example, long-term environmental monitoring data from control areas would provide data both for evaluating the biotic potential of the area, as well as physical and chemical time-series data for oceanographic studies.

REFERENCES

1. MCKEE, J. E. Parameters of marine pollution–an overall evaluation. *In* T. A. OLSON, and F. J. BURGESS, *eds.* Publication and marine ecology. New York, Interscience Publishers, 1967. p. 259-266.
2. GUNNERSON, C. G. Optimizing sampling intervals. *In* Proceedings of the IBM Scientific Computing Symposium on Water and Air Resource Management, Thomas J. Watson Research Center, Yorktown Heights, N. Y., Oct. 23-25, 1967. Harrison, N. Y., International Business Machines Corporation, 1968. p. 115-140.
3. MCKEE, J. E., and H. W. WOLF, *eds.* Water quality criteria. 2d ed. Publication No. 3-A. Sacramento, State Water Quality Control Board, 1963. 548 p.
4. U.S. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION. Water quality criteria; report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, U.S. Government Printing Office, 1968. 234 p.
5. STEIN, J. E., and J. G. DENISON. Limitations of indicator organisms. *In* T. A. OLSON, and F. J. BURGESS, *eds.* Pollution and marine ecology. New York, Interscience Publishers, 1967. p. 323-335.
6. Panel reports of the Commission on Marine Science, Engineering and Resources. v. 1. Science and environment. Washington, U.S. Government Printing Office, 1969. 364 p.
7. KETCHUM, B. H., and W. L. FORD. Rate of dispersion in the wake of a barge at sea. *Transactions of the American Geophysical Union,* 33(5):680-684, Oct. 1952.
8. MACSMITH, W., JR. Offshore disposal of industrial waste. Presented at 42d Annual Conference, Water Pollution Control Federation, Dallas, Oct. 5-10, 1969. 8 p.
9. PEARSON, E. A., P. N. STORRS, and R. E. SELLECK. Some physical parameters and their significance in marine waste disposal. *In* T. A. OLSON, and F. J. BURGESS, *eds.* Pollution and marine ecology. New York, Interscience Publishers, 1967. p. 297-315.
10. NATIONAL RESEARCH COUNCIL COMMITTEE ON OCEANOGRAPHY. Radioactive waste disposal into Atlantic and Gulf coastal waters; a report from a working group of the Committee on Oceanography of the National Academy of Sciences–National Research Council. National Research Council Publication No. 655. Washington, National Academy of Sciences, 1959. 37 p.
11. NATIONAL ACADEMY OF SCIENCES COMMITTEE ON EFFECTS OF ATOMIC RADIATION ON OCEANOGRAPHY AND FISHERIES. Considerations on the disposal of radioactive wastes from nuclear-powered ships into the marine environment. National Research Council Publication 658. Washington, National Academy of Sciences–National Research Council, 1959. 52 p.
12. NATIONAL RESEARCH COUNCIL COMMITTEE ON OCEANOGRAPHY. Disposal of low-level radioactive waste into Pacific coastal waters. National Research Council Publication 985. Washington, National Academy of Sciences -National Research Council, 1962. 87 p.
13. HOOD, D. W. The disposal of chlorinated hydrocarbons at sea. Unpublished data [Project 69, Reference 54-47T]. College Station, Texas A&M Research Foundation, 1954. 33 p.
14. CLARKE, W. D., and M. NEUSHUL. Subtidal ecology of the southern California coast. *In* T. A. OLSON, and F. J. BURGESS, *eds.* Pollution and marine ecology. New York, Interscience Publishers, 1967. p. 29-42.
15. LEWIS, G. B., and A. H. Seymour. Distribution of zinc-65 in plankton from offshore waters of Washington and Oregon, 1961-1963. *Ocean Science and Ocean Engineering,* 2:956-967, 1965.
16. OSTERBERG, C. Radioactivity from the Columbia River. *Ocean Science and Ocean Engineering,* 2:968-979, 1965.

17. Marine resources activities in Texas. Industrial Economics Research Discussion, National Science Foundation Sea Grant Program, Texas A&M University, 1969. 202 p.
18. SCHUYLER, S., and G. HEIMERDINGER. Continental margin data collection pilot project; a Division of Research and Development open-file report (CT-02-69-45). [Cincinnati], U.S. Department of Health, Education, and Welfare, 1970. [81 p.] [Restricted distribution.]
19. U.S. BUREAU OF COMMERCIAL FISHERIES. Report of the Bureau of Commercial Fisheries for the calendar year 1966. Washington, U.S. Government Printing Office, 1968. 141 p.
20. BUELOW, R. W. Ocean disposal of waste material. *In* Transactions; National Symposium on Ocean Sciences and Engineering of the Atlantic Shelf, Philadelphia, Mar. 19-20, 1968. Marine Technology Society. p. 311-337.
21. STOERTZ, G. E., W. R. HEMPHILL, and D. A. MARKLE. Airborne fluorometer applicable to marine and estuarine studies. *Marine Technology Society Journal,* 3(6):11-26, Nov.-Dec. 1969.
22. Coast Guard outlines proposed oil surveillance plan. *Air/Water Pollution Report,* 7(50):438, Dec. 15, 1969.

V. INSTITUTIONAL FACTORS AND RECOMMENDATIONS

The purpose of this chapter is to review and summarize trends in marine disposal of solid wastes, to examine technological and institutional problems associated with marine disposal operations, and to make recommendations as to future legal, administrative, environmental research, and engineering development actions required in connection with marine disposal of solid waste.

SUMMARY OF TRENDS

Last Twenty Years

Analysis of historic data on waste disposal at sea for the 20-year period from 1949 to 1968 shows a four-fold increase in tonnage. Tonnages disposed at sea increased from an average of 1.7 million tons per year from 1949 to 1968 to 7.4 million tons per year for the 1964-68 period (Table 9). Atlantic coast discharges of industrial wastes and sewage sludge are five times as large as the operations on the Pacific and Gulf coasts combined.

It is emphasized that the tonnages shown on Table 9 do not include dredge spoil, explosives, and radioactive wastes. In compiling this table from Corps of Engineers records, it was assumed that once a given disposal operation was initiated, it continued unchanged over the ensuing years. Caution should be exercised in use of the data prior to 1959; Atlantic Coast tonnages are based on extrapolation of recent data and arbitrary doubling of the figures contained in the 1951[1] NAS-NRC report on the disposal of acid wastes by Redfield and Walford.

TABLE 9
MARINE WASTE DISPOSAL TONNAGES BY REGION IN FIVE-YEAR PERIODS FROM 1949-1968*

	1949-53	1954-58	1959-63	1964-68
PACIFIC COAST				
Total	487,000	850,000	940,000	3,410,000
Average/year	97,400	170,000	188,000	682,000
ATLANTIC COAST				
Total	8,000,000†	16,000,000‡	27,270,000	31,100,000
Average/year	1,600,000	3,200,000	5,454,000	6,200,000
GULF COAST				
Total	40,000§	283,000	860,000	2,600,000
Average/year	8,000	56,000	172,000	520,000
TOTAL U.S.	8,527,000	9,133,000	29,070,000	37,110,000
U.S. Average/year	1,705,400	1,826,600	5,814,000	7,422,000

* Figures do not include dredge spoil, radioactive wastes, and military explosives. Values are short tons.

† Based on data contained in the 1951-NAS-NCR report by Redfield and Walford.[1]

‡ Based on an arbitrary doubling of the 1949-53 tonnage figures which, fits a linear projection connecting with the detailed data available from 1949 onwards.

§ On-going disposal operations in the Gulf of Mexico originated in 1952.

The largest factor contributing to the 27.5 percent increase in tonnage from 1959-63 to 1964-68 was the increase in disposal of industrial wastes and sewage sludge. Fairly reliable data show that in 1959 industrial wastes discharged at sea amounted to about 2.2 million tons. In 1968, industrial wastes amounted to some 4.7 million tons or roughly double the 1959 disposal rate. Similarly, the amount of sewage sludge disposed at sea increased from 2.8 million tons in 1959 to 4.5 million tons in 1968.

Future Trends

It is almost certain that under prevailing conditions there will be increasing pressures to use the sea for disposal of the municipal and industrial wastes generated in rapidly expanding coastal zone metropolitan and industrial areas.

Municipal Wastes. According to the National Estuarine Pollution Study recently published by the FWPCA, the population of coastal counties in the United States increased by 78 percent during the period 1930 to 1960, as compared to a national growth rate of 46 percent.[2] Data from a variety of sources indicate that the population in the coastal zone will continue to grow at a rate substantially higher than the national population growth rate.[3,4] The coastal zone population is expected to more than double between 1960 and the year 2020, from 60 million to 139 million persons. This massive buildup in the coastal zone population will bring with it corresponding increases in generation of refuse, commercial wastes, demolition wastes, and sewage sludge.

Refuse. Conservative estimates indicate a national average of 6 to 7 pounds per person per day of municipal refuse (excluding sewage sludge) presently being generated; This totals over 256 million tons per year for the Nation as a whole.[5] Current population estimates indicate that at least 40 percent of this tonnage originates in the coastal zone.

Assuming that per capita waste production will increase at the same growth rate (4%) as that predicted for production of consumer goods, the amount of materials to be collected by municipal and private agencies is expected to rise to 8 pounds per day per person by 1980.[5] Assuming a marine coastal zone population of 96 million residents by 1980,[3] over 140 million tons of municipal solid wastes will be collected. It is estimated that the amount of land necessary to dispose of these wastes will nearly double from 1966 to 1976.[2]

Sewage Sludge. According to the results of the National Estuarine Pollution Study the amount of settlable and suspended solids (sludge) in municipal sewage generated from coastal areas served by sewers will increase from 1.3 million tons per year (dry weight) in 1960 to over 1.7 million tons per year in 1980, or an increase of over 400,000 tons.[2] These figures do not take into account suburban and rural populations not served by sewers. For example, the amount of sewage sludge generated annually in the Baltimore-Washington region is expected to increase from 70,000 tons (dry weight) in 1968 to about 166,000 tons in 1980.[6] By comparison, the amount of sludge barged to sea annually by the metropolitan area of the City of New York is expected to increase from 99,000 tons (dry weight) in 1960 to 220,000 tons in 1980, or an increase of 122 percent.[7]

Industrial Wastes. At present, the coastal counties contain 40 percent of all the manufacturing plants in the United States. Over half of these plants (totaling one-fifth of all the manufacturing plants in the United States) are concentrated in what amounts to the Boston-Norfolk coastal zone.[2] Major increases in the production of industrial waste in coastal areas are expected.

The growth potential for certain industries currently using marine disposal for a portion of their wastes (such as the chemical and oil refining industries) indicates that their projected growth rate for the '70s is considerably higher than the national growth rate. According to Aalund the growth rate of the petrochemical industry required to satisfy the demands for synthetic chemical products during the next decade will be double the national industrial growth rate.[8] Stormont has forecast a major increase in oil refinery capacity in order to keep pace with the projectd 1980 demand of 21 million barrels per day.[9] Geographically, the Gulf Coast area will probably remain the center for construction of new refinery and petro-chemical plants during the '70s, although if Alaskan and Canadian oil can be delivered cheaply to the Atlantic coast, a major expansion can also be anticipated there.

INSTITUTIONAL FACTORS IN SEA DISPOSAL

Both precedent and practice are resulting in growing interest in sea disposal of solid and liquid wastes. There are concurrent increases in coastal zone municipal and industrial waste production and marked decreases in the number of presently acceptable alternatives for disposal of these wastes. This reduction results from increasingly strict water and air pollution laws, and from the loss of land areas now used for solid waste landfill and for ponding of liquid wastes because of expansion of residential areas and increasing property values in industrial areas. As a result of this situation, the economics of sea disposal of municipal refuse are becoming increasingly attractive. Groups in major cities including San Francisco, New York, and Philadelphia have already shown substantial interest in proposed programs for ocean disposal of these wastes.

Marine disposal of various types of industrial sludges is also an economically attractive proposition to industrial plants in both coastal and midcontinent areas, even though costs of as much as $130 per ton wet weight have been reported (Table 2). During the last two years, there has been a marked increase in the number of inquiries to regulatory agencies by various industry representatives regarding the procedures involved in obtaining permission to dispose of wastes at sea. As noted in Chapter II, one proposal came from as far inland as West Virginia in the upper Ohio basin; here, cost studies showed it was cheaper to barge the wastes to sea than to treat them so as to meet the local stream standards. In addition, representatives from industrial firms already practicing marine waste disposal have indicated that unless other solutions to their waste disposal problems become available, they expect to continue their present marine disposal practices.

In summary, the present level of 62 million tons per year of wastes being barged to sea for disposal is expected to increase in the immediate future.

On the other side of the coin, the progressive increase in coastal zone population also creates increasing pressure for other uses of the sea, particularly the shallower nearshore areas. These uses include all types of water-oriented recreation (which in itself is a multimillion dollar industry), commercial fishing, various aspects of scientific research and engineering development, and in selected localities, the potential for development of offshore petroleum and mineral resources.

On a global scale, the role of the sea in maintaining all life is unknown, but it is considered a vital "balance wheel" by an increasing group of ecologists and conservationists. There are some marine waste disposal operations that are demonstrably or intuitively incompatible with maximum utilization of the sea. By contrast, there appear to be other cases where disposal of selected wastes will enhance or at least not damage the marine environment. In any event, it is clear that a substantial initial opposition to marine disposal can be expected because of potential conflict with other uses of the sea and the public's current concern with conservation of the environment. It is apparent that the burden of proof for the acceptability of marine disposal will rest on those proposing such programs.

Regulation and Enforcement

Perhaps the single most significant trend that will influence disposal of wastes at sea over the next decade is the keen and increasing public sensitivity to the need for protecting and preserving the environment. As a result of this situation there will be a definite trend toward stricter laws and enforcement procedures, backed by sizeable penalties governing the disposal of wastes. Therefore, obtaining authorization for new or expanded marine disposal operations in the future will require a major effort. Industries and municipalities seeking such authorization can anticipate requirements for comprehensive environmental research, development, and demonstration programs to prove that the selected ocean floor sites and the overlying water column can receive the proposed waste tonnages without damage.

PROBLEM AREAS

Areas of existing or potential problems associated with marine disposal operations include: legal aspects, documentation of existing disposal operations, and evaluation of environmental effects.

Legal Aspects

International law dictates that the high seas shall remain free for the use of all nations, beyond the outer limits of a coastal nation's territorial sea. This is clearly stated in international conventions to which the United States is a party. The Convention of the Territorial Sea and the Contiguous Zone proclaims that a coastal nation shall have limited jurisdiction on the high seas to a maximum limit of 12 miles from the baseline from which the territorial sea is measured (the United States exercises sovereignty only to the 3-mile limit.) The language is ambiguous, however, and must be interpreted to accord with a nation's international as well as national policies.

Legislation, which is fairly specific, has been established to regulate disposal activities resulting in pollution within the Territorial Sea and Inland Waters of coastal states. To date, however, there is no legislative enactment which specifically provides that any agency, department or official of the United States is vested with authority to prevent pollution of the seas from the discharge of solid waste beyond the outer boundaries of the Territorial Sea. Specific legislation is imperative if the resources of the oceans are to be preserved for future generations.

The lack of authority has resulted in uncertainty as to how much, if any, responsibility should be assumed by individual Federal agencies with an interest in marine disposal of wastes. This vacuum has been filled in some cases by State agencies. A partial compendium of Federal and State laws and agencies has been compiled (Appendix E).

Until recent legislation created the U.S. Environmental Protection Agency, the Corps of Engineers had the broadest authority at least to the three-mile limit. Some Corps districts have acted on the assumption that they have jurisdiction; other districts contend that they do not have such jurisdiction. In other instances there is a question of overlap of jurisdiction wherein a Federal agency and a state agency may both have responsibilities and authority related to marine waste disposal operations in a given area. Such regulations as exist pertaining to marine disposal operations are scattered among various Federal laws. These regulations are generally not clearly defined and do not set forth precisely what is and what is not allowable as far as marine disposal is concerned. As a result, what may be considered acceptable disposal practice in one Corps district would not be authorized in another district.

The lack of explicit jurisdictional authority is reflected by the absence of effective monitoring and surveillance of tug and barge waste disposal activities. After the occasional initial studies conducted either by industry or interested regulatory agencies, only at New York have there been follow-on enforcement monitoring programs. Thus, present compliance with whatever disposal procedures that regulatory agencies set up when an applicant is granted permission to dispose of wastes at sea is primarily a matter of cooperation. Efforts at operating control are essentially limited to occasional fines in the New York area only. No instance could be found where a permit has ever been rescinded or not renewed because of past infractions of prescribed disposal procedures.

Even though water quality standards have been established in some cases, they are for the most part based on fragmentary evidence and more concerned with protecting the aesthetic enjoyment of the environment (e.g., color, floatables, aquatic growths, etc.) than with potential larger-scale effects on the marine food chain.

As a consequence of both the unclear legal aspects and the lack of effective water quality standards, very few applications for marine disposal authorization are denied, even though in some cases strong disapproval of the proposed operation has been voiced by several conservation agencies.

Documentation of Existing Disposal Operations

Documentation of existing disposal operations varies widely, and in some Corps districts effective record keeping is lacking. It is apparent that record preparation and maintenance by agencies responsible for marine disposal is an essential first step in enforcement monitoring of disposal operations. Equally important is a formalized reporting system that would result in the preparation of regional and national summaries on an annual or biannual basis. Such documentation is essential to many aspects of solid waste research, operations, and management.

It has been found that exchange and dissemination of information on solid waste marine disposal operations is poor. For example, most Corps of Engineers district offices have only a general idea of how a given problem is handled by another district, even though in some cases the distances separating them may only be a few hundred miles. Similarly, while there may be several Federal, State, and local agencies involved in various aspects of barge-delivered oceanic disposal of wastes from any one city, the survey indicates that rarely would more than one of these agencies have a reasonably comprehensive picture of the total activities in that city or coastal area. This lack of communication between agencies and the restriction of interest in a given agency to only certain types of wastes indicates the need for an effective information management system.

The present lack of effective data management seriously hampers agencies handling applications for offshore disposal authorization with resulting delays in processing and announcement of decisions. For example, industrial firms commonly must wait for periods up to a year for decisions on requests to dispose of their wastes at sea even though the same wastes may be sanctioned for disposal in a city only 200 miles away.

The technical evaluation and management of marine disposal of solid wastes is a relatively recent development which cuts across several technical fields, and which has the characteristic problems typical of developing interdisciplinary technical areas. The pertinent literature is widely scattered in relatively obscure journals or in institutional reports of very limited distribution.

Because of the lack of information regarding current disposal activities and their environmental effects, regulatory or conservation agencies responsible for passing on applications for new marine disposal operations commonly are faced with authorizing or rejecting the application on the basis of totally inadequate technical information.

Industrial firms are also hampered by this same lack of information in evaluating marine disposal as a potential solution to their waste disposal problems.

It is evident that as ocean disposal activities expand, effective reporting, documentation, summary, and information dissemination procedures must be put into effect. Such procedures would substantially benefit all parties concerned.

Evaluation of Environmental Effects

Information presented on the environmental effects of barging wastes to sea demonstrates the lack of adequate technical data on short (Chapter III) and long-term responses of the marine environment to oceanic disposal of solid waste. Environmental effects of past and present discharges are not even qualitatively known, let alone measured. The major exception to this is the well-known propensity of garbage and similar materials to float; if these wastes are barged to coastal waters, they float shoreward.

The survey of current monitoring practices and needs (Chapter IV) indicated that there is no effective ongoing monitoring to determine environmental effects of disposal activities. Limited initial studies of short-term environmental effects sometimes conducted either by industry or interested regulatory agencies are not followed up. Thus, there is a serious knowledge gap regarding both the short- and long-term effects that ocean waste disposal operations have on the marine environment. This lack of knowledge results in the previously noted situation wherein responsible officials must evaluate applications for disposal authorization without adequate factual background. Even more important, it is not possible to assure either the discharger or the public that effects of marine disposal activities are not damaging.

With the possible exception of radioactive materials (including fallout), there is sufficient water in the lower layers of the ocean to dilute waste materials below detectable concentrations. It follows that waste should be discharged as deep as possible and should be dispersed as much as is feasible in order to hasten dilution and subsequent assimilation. However, there are almost certainly some wastes where sea disposal presents a greater hazard than the alternatives. For example, refractory organic pesticides are concentrated in the food chain; for this class of materials, pyrolysis is the preferred disposal method.

As indicated, there are a number of important basic oceanographic and ecologic questions that must be answered before we have an adequate understanding of the ocean's environmental response to waste disposal. (Chapter III). These include: the character of dilution and dispersion of a waste field in the upper (mixed) layer of the sea, circulation in the intermediate and deeper ocean layers, exchange of water between the surface and deeper layers, behavior and fate of pollutants in the marine environment, uptake and retention of specific elements or compounds by food chain organisms, and sublethal or chronic long-term effects of waste materials on various biologic organisms.

It is significant that a virtually identical list of principal unresolved problems was prepared by Revelle and the NAS-NRC Committee on Oceanography in 1956 in connection with a study of the biological effects of atomic radiation.[12]

For areas where baseline environmental data are adequate, accurate prediction of the suitability of sea floor disposal sites should not be particularly difficult. There is a further need to demonstrate and verify the ocean's capability for assimilating solid waste. Good environmental engineering practice demands that adequate preliminary studies be carried out to evaluate the response of the marine environment prior to undertaking large-scale disposal operations. Marine waste disposal may be economically desirable, but it must also be environmentally acceptable.

In order to carry out such technical studies, substantial funding will be required. Because of the magnitude of the funds required for such technical work, it is doubtful that a given municipality could pay for this research. Thus, it would appear that the Federal Government should continue to underwrite a substantial portion of such research work. There are existing provisions for such support by the office of Solid Waste Management.

In addition, industry must be prepared to fund technical evaluations in connection with their own disposal activities. To date, most of the work funded by industry on the environmental effect of waste disposal have focused on initial studies to determine short-term environmental response. There is an even greater responsibility to conduct comprehensive long-range studies so as to insure an understanding of possible long-term deleterious effects on the biota.

RECOMMENDATIONS

In order to conserve and utilize the environmental and other resources of the sea, it is recommended that: (1) the Federal Government, in conjunction with the coastal States, evaluate existing conventions, treaties, laws, and regulations pertaining to marine waste disposal and adopt appropriate legislation and regulations to establish an effective legal framework; (2) the Federal Government establish uniform application and review procedures for marine waste disposal permits and minimum standards for baseline surveys, monitoring procedures, and related data management and dissemination; (3) The Federal Government support and participate in environmental research leading to effective functional designs and operating criteria for beneficial or nondamaging disposal of wastes into the marine environment; (4) the Federal Government support engineering research, development, and demonstration of marine waste disposal systems, for those classes of wastes that do not damage the environment. This should include optimization of materials handling, processing, and transportation facilities, and monitoring systems and procedures.

REFERENCES

1. REDFIELD, A. C., and L. A. WALFORD. A study of the disposal of chemical waste at sea; report of the Committee for Investigation of Waste Disposal. National Research Council Publication No. 201. Washington, National Academy of Sciences, 1951. 49 p.
2. The national estuarine pollution study; report of the Secretary of the Interior to the U.S. Congress pursuant to Public Law 89-753, the Clean Water Restoration Act of 1966, 91st Cong., 2d sess. v. 2. Washington, U.S. Government Printing Office, 1970. p. 59-340.
3. WINSLOW E., and A. B. BIGLER. A new perspective on recreational use of the ocean. *UnderSea Technology*, 10(7):51-55, July 1969.
4. Panel reports of the Commission on Marine Science, Engineering and Resources, v. 1. Science and environment. Washington, U.S. Government Printing Office, 1969. 364 p.
5. BLACK, R. J., A. J. MUHICH, A. J. KLEE, H. L. HICKMAN, JR. and R. D. VAUGHAN. The national solid waste survey; an interim report. [Cincinnati], U.S. Department of Health, Education, and Welfare, [1968]. 53 p.
6. BECHTEL, INCORPORATED. FWPCA waste management study. v. 1. The waste management concept; inland and ocean disposal of selected wastes. San Francisco, 1969. 167 p.
7. Personal communication. N. NASH, Division of Plant Operations, New York City Bureau of Water Pollution, to R. P. BROWN, Dillingham Corporation, May 1, 1969.
8. AALUND, L. R. Forecast for the seventies–petrochemical. *Oil and Gas Journal*, 67(45):172-174, Nov. 10, 1969.
9. STORMONT, D. H. Forecast for the seventies–refining. *Oil and Gas Journal*, 67(45):167-171, Nov. 10, 1969.
10. Everybody produces it; nobody wants it. *Seahorse*, 3(8):6, 1969.
11. Where to dispose of our refuse? Some say in the sea. New England Marine Resources *Information* 2, June-July 1969. Narragansett, R. I., New England Marine Resources Information Program. 2 p.
12. NATIONAL ACADEMY OF SCIENCES COMMITTEE ON EFFECTS OF ATOMIC RADIATION ON OCEANOGRAPHY AND FISHERIES. The effects of atomic radiation on oceanography and fisheries. National Research Council Publication 551. Washington, National Academy of Sciences–National Research Council, 1957. 137 p.

APPENDIX A

STANDARD QUESTIONNAIRE

INVENTORY OF OCEANIC DISPOSAL PRACTICES
FOR SOLID WASTES AND INDUSTRIAL SLUDGES

FORM APPROVED
BUDGET BUREAU
No. 85-S 68011

INVENTORY OF OCEANIC DISPOSAL PRACTICES FOR SOLID WASTES AND INDUSTRIAL SLUDGES

A. General Information

1. Date: Year________ Month ____________ Day ______________________________
2. Interviewer____
3. Time started_____________ Time completed __________________________________
4. Interviewee name: ____
5. Title: ____
6. Phone Number: ____
7. Organization name: ____
8. Address: ____

B. Federal, State and Municipal Agencies or Organizations

1. What information can you supply regarding where, when, and how often oceanic disposal is taking place from your city?
2. What organizations or companies do you know of that are involved in each dumping activity?
3. What is the nature of the material being dumped (i.e. a description of the physical and chemical composition), and the approximate weights or volume of material involved in each operation?
4. What is the approximate location of the existing offshore dumping sites? (Can you supply information as to the distance from the coast and water depths where the dumping takes place?
5. Is the actual dumping concentrated in a specific area or is it scattered at random?
6. What organizations are currently responsible for regulation and surveillance of dumping operations?
7. What means exist for determining that dumping is, in fact, carried out beyond the three mile limit or in the areas (and depths) specified in questions 4 and 5?
8. What is the approximate cost of each of the dumping operations, and what is the size and type of tugs, barges and loading equipment used?
9. What is the history for each dumping operation? Specifically, when begun and what variations have occurred with respect to present operations in regard to nature and volume of material, frequency of dumping, etc.?
10. Have there been any other dumping operations undertaken in the past ten years which are not now active—if so, please specify where, when, by whom, volume, etc.?
11. What evidence is there which indicates the fate of the dumped material or of the effects that the waste material has had on the environment. (*i.e.* presence of garbage on beaches, discoloration of water, odors, etc.)?

12. Are there any proposed new marine solid waste disposal activities under development in your city, state or adjacent areas?

13. What other Federal, State or Municipal agencies, organizations, commercial companies or private individuals might have additional pertinent information on oceanic dumping activities?

14. What reports, publications or other pertinent literature have you released concerning past, present or future marine solid waste disposal within your area of operations?

C. Commercial Companies and Private Individuals

Information supplied for this portion of the questionnaire is considered to be *confidential* and will be used only to prepare summaries of various regional operations. The information you provide and the identity of individual companies and operations will not be disclosed.

1. What is the nature of the material (i.e. a description of the physical and chemical composition) and the approximate weight and volume of the material involved in each operation?

2. At what estimated distance from the coast and in what water depths does the dumping actually take place?

3. Is the material usually dumped in one specific area or is it scattered at random?

4. What organizations are currently responsible for regulation and observation of your dumping operations?

5. What means exist for determing that dumping is, in fact, carried out beyond the three mile limit or in the areas (and depths) specified in questions 2 and 3?

6. What is the approximate cost of each of the dumping operations, and what is size and type of tugs, barges, and loading equipment used?

7. What has been the history for each dumping operation? Specifically, when begun and what variations have occurred with respect to present dumping operations in regard to nature and volume of material, frequency of dumping, etc.?

8. Are you aware of other dumping operations undertaken in the past five years which are not now active if so, specify where, when, by whom, volume, etc.?

9. Is there any evidence indicating the fate of the dumped material or of the effects that the waste material has had on the environment. (*i.e.*, presence of garbage on beaches, discoloration of water, odors, etc.)?

APPENDIX B

CHARACTERISTICS OF MARINE WASTE DISPOSAL AREAS

This appendix was compiled by

JAMES L. VERBER

Food and Drug Administration, Public Health Service,
U.S. Department of Health, Education, and Welfare

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NOTES

1. Spoil Area—separated by channel or adjacent to each other, not considered two sites.
2. Spoil Zone, paralleling channel, may be several miles in length and/or consist of many small areas.
3. Discontinued for use shown.
4. Center point of large disposal area, 25 square miles or more.
5. Data supplied from Dillingham file, site not verified.
6. Position approximate.
7. Duplicate site.

This compilation of sites does not include locations dicsontinued for 20 or more years.

Abbreviations:
CE—Corps of Engineers records
C&GS—Coast and Geodetic Survey chart
AEC—Atomic Energy Commission
NAS-NRC—National Academy of Science-National Research Council

APPENDIX B

CHARACTERISTICS OF MARINE WASTE DISPOSAL AREAS

Atlantic Coast Disposal Areas

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
Dredging Spoils						
44° 26′	67° 46′	22	4	1201	7	Cape Split, Me. (C&GS)
44° 24′	68° 55′	23	3	1205	7	Belfast, Me. (C&GS)
44° 14′	68° 55′	16	6	1203		#1 Camden, Me. (CE)
44° 12′	69° 01′	31	2	1203		#2 Camden, Me. (CE)
44° 07′	69° 03′	24	2	1203		#3 Rockland, Me. (CE)
44° 16′	68° 58′	18	2	1203		#4 Lincolnville, Me. (CE)
43° 56′	69° 24′	17	2	313		#5 Round Pond, Me. (CE)
43° 40′	70° 10′	16	3	325		Portland, Me. (C&GS)
43° 38′	70° 10′	17	2	325		#6 Portland, Me. (CE)
43° 40′	70° 08′	12	4	325		Portland, Me. (C&GS)
43° 34′	70° 02′	24	8	1204		Portland, Me. (C&GS)
43° 19′	70° 27′	14	1	1205		#7 Kennebunk Port, Me. (CE)
42° 50′	70° 34′	29	7	1206		Portsmouth, N.H. (C&GS)
42° 27′	70° 44′	25	5	1207		#10 Boston, Mass. (CE)
42° 21′	70° 40′	29	7	1207		#13 Boston, Mass. (CE) Prov. #11
42° 32′	70° 40′	30	3	1207		#8 Boston, Mass. (CE)
42° 30′	70° 46′	20	2	1207		#9 Boston, Mass. (CE)
42° 16′	70° 41′	14	3	1207		#11 Boston, Mass. (CE) Prov. #13
42° 33′	70° 47′	11	1	1207		#12 Boston, Mass. (CE)
42° 16′	70° 34′	29	7	1207		Boston, Mass. (C&GS)
41° 38′	70° 02′	5	1	114SC		Monomoy Is., Mass. (C&GS)
41° 36′	70° 17′	5	1	114SC		Hyannis, Mass. (C&GS)
41° 36′	70° 41′	3	1	1210		W Falmouth, Mass. (C&GS)
42° 00′	70° 34′	14	1	1208		#14 Plymouth, Mass. (CE)
40° 45′	70° 50′	32	30	1107		Martha's Vineyard, Mass. (C&GS)
41° 21′	70° 06′	8	3	1209		#15 Nantucket Is., Mass. (CE)
41° 34′	70° 50′	3	1	252		#16 West Island, Mass. (CE)
41° 23′	71° 18′	18	5	1210		#17 Narragansett Bay, R.I. (CE)
41° 21′	71° 21′	18	5	1210		Narragansett Bay, R.I. (C&GS)
41° 11′	71° 31′	21	1	1210		#18 Block Is., R.I. (CE)
41° 18′	71° 55′	18	2	116SC		Stonington, Conn. (CE)
41° 18′	72° 00′	12	2	116SC		North Dumpling, Conn. (CE)
41° 16′	72° 05′	11	2	1211		New London, Conn. (CE)
41° 13′	72° 05′	8	5	1211		Little Gull Is. (CE)
41° 16′	72° 11′	14	1	1211		Niantic Bay, Conn. (CE)
41° 11′	72° 14′	20	6	1211		Orient Pt., L.I., N.Y. (CE)
41° 14′	72° 20′	19	2	1212		Cornfield Shoal (CE)
41° 13′	72° 31′	19	2	1212		Clinton Harbor, Conn. (CE)
41° 04′	72° 35′	19	2	1212		Mattituck, L.I., N.Y. (CE)
41° 11′	72° 43′	12	4	1212		Falkner Island, Conn. (CE)
41° 10′	72° 48′	12	5	1212		Branford, Conn. (CE)
41° 09′	72° 53′	11	5	1212		New Haven, Conn. (CE)
41° 07′	73° 02′	11	4	1212		Milford. Conn. (CE)
41° 01′	73° 07′	26	2	1212		Port Jefferson, L.I., N.Y. (CE)
41° 04′	73° 12′	11	3	1213		Bridgeport, Conn. (CE)
41° 00′	73° 13′	18	4	1213		Smithtown, Bay, L.I., N.Y. (CE)
41° 04′	73° 17′	11	3	1213		Southport, Conn. (CE)
40° 59′	73° 20′	15	4	1213		#23 S. Norwalk, Conn. (CE) Prov. #19
40° 59′	73° 26′	24	4	1213		South Norwalk, Conn. (CE)
41° 01′	73° 27′	13	3	1213		South Norwalk, Conn. (CE)
40° 59′	73° 31′	18	3	1213		Stamford, Conn. (CE)
40° 24′	73° 51′	15	10	1215		Sandy Hook, N.J. (MUD) (CE)
40° 23′	73° 49′	17	10	1215		Sandy Hook, N.J. (CELLAR) (CE)
40° 13′	73° 46′	36	11	1215		Ashbury Park, N.J. (WRECK) (CE)
40° 06′	74° 02′	3	1	795		Manasquan Inlet, N.J. (CE)
39° 21′	74° 25′	3	1	1217		Absecon, N.J. (CE)

Atlantic Coast Disposal Areas–(Cont.)

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
38° 55′	75° 00′	4	2	1219		Crow Shoal, N.J. (CE)
38° 56′	75° 01′	1	2	1219		Crow Shoal, N.J. (CE)
38° 55′	74° 54′	4	1	1219		Cold Spring, N.J. (CE)
38° 58′	75° 03′	8	3	1219		Cape May, N.J. (C&GS)
37° 00′	75° 40′	11	27	1222		Norfolk, Va. (CE)
36° 48′	75° 54′	7	4	1227		Virginia Beach, Va. (CE)
34° 39′	76° 40′	8	3	1234	3	Beaufort, N.C. (C&GS)
34° 39′	76° 42′	9	4	1234	3	Beaufort, N.C. (C&GS)
34° 39′	76° 43′	9	4	1234		Beaufort, N.C. (C&GS)
33° 48′	78° 02′	7	3	1236		Cape Fear, N.C. (CE)
33° 11′	79° 08′	3	2	1237		Winyah Bay, S.C. (CE)
32° 40′	79° 47′	6	4	1239		Charlestown, S.C. (CE)
32° 09′	80° 36′	4	6	1240		Port Royal, S.C.-A (CE)
32° 05′	80° 36′	6	8	1240		Port Royal, S.C.-B (CE)
31° 58′	80° 43′	9	6	1240	3	Savannah, Ga. (CE)
31° 57′	80° 45′	8	5	1240		Savannah, Ga. (CE)
31° 04′	81° 15′	5	10	1242	3	St. Simons, Ga. (CE)
31° 02′	81° 18′	6	8	1242		St. Simons, Ga. (CE)
30° 42′	81° 24′	6	1	1242		Fernandina Beach, Fla.-A (CE)
30° 42′	81° 21′	7	3	1242		Fernandina Beach, Fla.-B (CE)
30° 41′	81° 22′	6	3	1242		St. Mary's River, Fla. (C&GS)
30° 23′	81° 21′	8	6	1243		Jacksonville, Fla. (CE)
28° 23′	80° 34′	<3	1	1245		Canaveral, Fla. (CE)
27° 27′	80° 15′	6	1	1247		Fort Pierce. Fla. (CE)
25° 46′	80° 05′	11	1	1248		Miami Beach, Fla.-A (CE)
25° 45′	80° 06′	5	1	1248		Miami Beach, Fla.-B (CE)
25° 45′	80° 07′	3	1	1248		Miami Beach, Fla. (C&GS)
			Industrial			
44° 26′	67° 46′	22	4	1201	7	Cape Split, Me.
44° 23′	68° 50′	23	3	1203	7	Belfast, Me.
42° 25′	70° 35′	52	10	1207	7	Boston, Mass.
41° 03′	71° 29′	26	17	1211		Montauk Pt., L.I., N.Y.
40° 34′	71° 57′	34	30	1000	5	Montauk Pt., L.I., N.Y.
40° 20′	73° 40′	13	15	1215	4	Sandy Hook, N.J. (CE)
38° 56′	74° 07′	21	40	1000	5	Cape May, N.J.
38° 54′	73° 17′	35	80	1000	4,7	Cape May, N.J.
38° 32′	74° 20′	24	37	1000	4	Cape May, N.J. (CE)
38° 30′	72° 06′	1240	123	1000	7	Md.-Del. State Line (CE)
38° 22′	74° 15′	29	47	1000	4	Cape May, N.J. (CE)
38° 10′	73° 22′	980	97	1000	4,7	Cape May, N.J. (CE)
37° 20′	74° 44′	26	55	1000		Norfolk, Va.
36° 55′	74° 53′	16	40	1000	4	Norfolk, Va.
32° 43′	79° 00′	14	43	1001		Charleston, S.C.
			Explosives and Toxic Chemical Ammunition[1]			
42° 25′	70° 35′	52	10	1207	4,7	Boston, Mass.
41° 33′	65° 33′	1305	196	1000	4,7	Cape Cod, Mass.
40° 44′	70° 51′	35	45	1000	4	Montauk Pt., N.Y.
39° 38′	71° 00′	1250	97	1000	4	Montauk Pt., N.Y., CHASE X, VIII, XII, CHASE XXI[2]
38° 53′	72° 23′	1286	100	1000	4	Cape May, N.J., CHASE XXII[2]
38° 49′	72° 14′	1280	105	1000	7	Cape May, N.J., CHASE II

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[1] Shown on C&GS Charts.

[2] Projects conducted in 1969 and 1970.

Atlantic Coast Disposal Areas–(Cont.)

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
38° 30′	72° 06′	1240	123	1000	3,4,7	Md.-Del. State Line
38° 05′	73° 24′	1061	83	1000	7,4	Delaware Bay, N.J.
37° 19′	74° 15′	730	64	1000	4	Cape Charles, Va.
37° 12′	74° 21′	1093	63	1000		Norfolk, Va.,, CHASE III
37° 11′	74° 26′	1005	64	1000		Norfolk, Va., CHASE IV
36° 30′	74° 18′	1243	80	1000	4	Va.-N.C. State Line CHASE VII
32° 15′	78° 41′	225	59	1001	3,4	Charleston, S.C.
31° 40′	77° 00′	1175	145	1001	4	Savannah, Ga.
31° 40′	75° 56′	1450	168	1001		Savannah, Ga., CHASE IX
30 33′	79° 52′	171	81	1001	3,4	Jacksonville, Fla.
29° 20′	76° 00′	2630	244	1001	4	Cape Kennedy, Fla., CHASE X^2
28° 15′	77° 51′	560	137	1001	4	Cape Kennedy, Fla.
25° 28′	79° 40′	397	24	1002	3,4	Miami, Fla.
			Radioactive			
43° 49′	45° 00′	>2000	>800	- - -		Central Atlantic (AEC)
42° 25′	70° 35′	52	10	1207	7	Boston, Mass. (AEC)
42° 07′	45° 00′	>2000	>800	- - -		Central Atlantic (AEC)
41° 33′	65° 33′	1305	196	1000	7	Cape Cod, Mass. (NAS-NRC)
38° 41′	45° 00′	>2000	>800	- - -		Central Atlantic (AEC)
38° 30′	72° 06′	1240	123	1000	7	Maryland-Del. State Line (AEC)
37° 50′	70° 35′	2084	208	1000		Md.-Va. State Line (AEC)
37° 07′	45° 00′	>2000	>800	- - -		Central Atlantic (AEC)
36° 56′	74° 23′	945	78	1000		Norfolk, Va. (AEC)
36° 20′	45° 00′	>2000	>800	- - -		Central Atlantic (AEC)
34° 32′	76° 40′	10	10	1233		Beaufort, N.C. (AEC)
34° 15′	76° 35′	14	27	1001	6	AEC information shows site at 35° 15′ (on dry land) could be area shown (NAS-NR)
33° 55′	75° 11′	1897	83	1001		Cape Lookout, N.C. (AEC)
32° 52′	75° 52′	1600	205	1001		Charleston, S.C. (AEC)
32° 50′	75° 20′	2125	230	1001		Charleston, S.C. (AEC)
32° 33′	75° 54′	1450	230	1001		Charleston, S.C. (AEC)
32° 30′	75° 45′	1606	140	1001		Charleston, S.C. (AEC)
31° 53′	76° 28′	1340	220	1001		Savannah, Ga. (AEC)
31° 35′	76° 12′	1440	235	1001		Savannah, Ga. (AEC)
31° 32′	76° 30′	1460	220	1001		Savannah, Ga. (AEC)
31° 27′	81° 10′	< 10	- - -	1001	6	Sapelo Is., Ga. (AEC)
31° 27′	76° 48′	1350	215	1001		Savannah, Ga. (AEC)
31° 10′	76° 31′	1550	257	1001		Jacksonville, Fla. (AEC)
31° 05′	76° 35′	1600	250	1001		Jacksonville, Fla. (AEC)
29° 38′	77° 27′	495	200	1001		St. Augustine, Fla. (AEC)
			Sewage Sludge			
40° 25′	73° 45′	12	12	1215		New York City, N.Y. (CE)
38° 46′	74° 47′	11	12	1219		Cape May, N.J. (CE)

APPENDIX B

CHARACTERISTICS OF MARINE WASTE DISPOSAL AREAS

Pacific Coast Disposal Areas

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
Industrial						
48° 20'	124° 53'	130	5	6102	6	Straits of Juan de Fuca, Wash.
48° 10'	126° 00'	643	75	6102	6	Cape Flattery, Wash.
37° 35'	122° 50'	44	20	5502	7	San Francisco, Calif.
37° 35'	122° 51'	45	14	5072		San Francisco, Calif.
37° 42'	122° 40'	18	9	5072		San Francisco, Calif.
33° 40'	119° 32'	1060	33	5101	5	Port Hueneme, Calif.
33° 38'	118° 25'	485	11	5101		San Pedro, Calif.
33° 37'	118° 40	459	15	5101		Santo Cruz Is., Calif.
32° 45'	117° 36'	580	20	5101	6	San Diego, Calif.
Dredge Spoils						
46° 56'	124° 07'	5–6	0.5	6002		Gray's Harbor, Wash. * (CE)
46° 42'	124° 10'	15	7	6185		Willipa Bay, Wash. (CE)
46° 14'	124° 10'	21	4	6151		Columbia River, Ore. B (CE)
46° 12'	124° 07'	23	7	6151		Columbia River, Ore. A (CE)
46° 11'	124° 09'	21	6	6151		Columbia River, Ore. F (CE)
45° 34'	123° 59'	12	1	6112		Tillamook, Ore. (CE)
44° 36'	124° 05'	3	1	6055		Yaquina River, Ore. (CE)
44° 01'	124° 09'	10	1	6023		Siuslaw River, Ore. (CE)
43° 40'	124° 14'	15	1	6004		Umpqua River, Ore. (CE)
43° 21'	124° 22'	13	1	5984		Coos Bay, Ore. (CE)
43° 07'	124° 27'	6	1	5971		Coquille River, Ore. (CE)
42° 24'	124° 29'	11	1	5951		Rogue River, Ore. (CE)
40° 46'	124° 16'	28	5	5832		Humbolt, Calif. (CE)
37° 47'	122° 32'	8	2	5502		San Francisco, Calif. (CE)
37° 46'	122° 38'	13	10	5502		San Francisco, Calif. (CE)
*Entrance Channel						
Explosives and Toxic Chemical Ammunition[1]						
59° 04'	144° 37'	803	55	8500	4	Cape Suckling, Alaska
54° 57'	134° 30'	426	43	8500	3,4	Dall Is., Alaska
54° 45'	134° 40'	1175	52	8500	4	Dall Is., Alaska
51° 22'	178° 19'[2]	1000	30	9000	4	Amchitka Is., Alaska CHASE VI
48° 51'	126° 50'	878	34	8500	3,4	Cape Flattery, Wash.
48° 16'	126° 59'	1430	66	8500	4	Cape Flattery, Wash.
						CHASE XVI[3], XVII[3], XVIII[3], XIX[3], XX[3]
39° 33'	125° 46'	1950	75	5002		CHASE V
37° 40'	123° 25'	1201	45	5502	4,7	San Francisco, Calif. CHASE I
37° 25'	125° 30'	2400	126	5002	3,4	San Francisco, Calif.
37° 10'	123° 23'	1759	47	5002	3,4	Pigeon Pt., Calif.
37° 00'	124° 00'	1911	78	5002	4	Pigeon Pt., Calif.
36° 22'	125° 30'	2480	162	5002	4	Point Sur., Calif.
36° 00'	123° 37'	2000	88	5002	3,4	Point Sur., Calif.
34° 38'	121° 48'	2144	58	5002	4	Pt. Arguello, Calif.
33° 17'	118° 48'	650	34	5101	3,4	Los Angeles, Calif.
32° 55'	118° 53'	945	52	5101	4	Los Angeles, Calif.
32° 45'	117° 36'	580	20	5101	4	San Diego, Calif.
32° 42'	117° 37'	602	20	5101	3,4	San Diego, Calif.
31° 40'	118° 26'	1020	85	5002	4	Punta Bunta, Mexico

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[1] Shown on C&GS Charts.

[2] East Longitude.

[3] CHASE projects conducted in 1969 and 1970.

Pacific Coast Disposal Areas–(Cont.)

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
Radioactive						
52° 05′	140° 00′	2030	430	8500	7	Cape Scott, Canada (AEC)
51° 30′	136° 31′	1965	320	8500		Cape Scott, Canada (AEC)
50° 56′	136° 03′	2040	285	8500		Cape Scott, Canada (AEC)
40° 07′	135° 24′	1090	506	9000		Cape Mendacino, Calif. (AEC)
37° 39′	123° 26′	1229	45	5002		San Francisco, Calif. (AEC)
34° 58′	174° 52′	3055	425	9000		Midway Island (AEC)
33° 39′	119° 28′	1060	33	5101		Port Hueneme, Calif. (AEC)
32° 00′	121° 30′	1207	215	5020		San Diego, Calif. (AEC)
30° 43′	139° 06′	>2500	850	9000		Los Angeles, Calif. (AEC)
21° 28′	157° 25′	2000	70	9000		Oahu, Hawaii (AEC)
Garbage (Refuse)						
37° 35′	122° 50′	44	20	5502	7	San Francisco, Calif.
33° 17′	118° 10′	409	22	5101		Catalina Is., Calif.
32° 27′	117° 16′	25	8	5101	6	San Diego, Calif.

APPENDIX B

CHARACTERISTICS OF MARINE WASTE DISPOSAL AREAS

Gulf Coast Disposal Areas

Industrial

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
29° 20′	88° 39′	40	60	1007	5	Pascagoula, Miss.
29° 11′	94° 30′	9	19	1007		Galveston, Texas
29° 10′	93° 40′	10	35	1007		Sabine, Texas
29° 07′	94° 26′	8	21	1007		Galveston, Texas
29° 05′	88° 00′	400	70	1007	5	Mobile Bay, Ala.
29° 02′	94° 39′	9	18	1007		Galveston, Texas
28° 59′	94° 35′	10	22	1007		Galveston, Texas
28° 39′	88° 50′	500	24	1007	4	South Pass. Miss. Delta, La.
28° 10′	89° 25′	655	53	1007	4	South Pass. Miss. Delta, La.
27° 57′	94° 37′	50	85	1007		Galveston, Texas
27° 48′	94° 54′	160	90	1007	4	Galveston, Texas
27° 49′	94° 30′	120	90	1007	4	Galveston, Texas
27° 36′	94° 36′*	400	110	1007	4	Galveston, Texas
27° 33′	94° 57′	400	110	1007		Galveston, Texas
27° 35′	95° 20′	460	100	1007	4	Corpus Christi, Texas
27° 30′	94° 10′*	455	121	1007	4	Galveston, Texas

* Area 15 by 20 miles used by several companies and, in general, agreed upon by letter of no objection from Corps of Engineers, Galveston District.

Explosives and Toxic Chemical Ammunition

						Comment[1]
29° 52′	89° 40′	1	0.5	1268		Lake Borgne, La.
29° 22′	87° 15′	290	57	1003	3,4	Pensacola, Fla.
28° 30′	89° 10′	335	28	1003	3,4	South Pass. La.
28° 25′	88° 55′	650	38	1003	4	South Pass. La
27° 40′	94° 30′	455	88	1007	3,4	Matagorda Bay, Texas
27° 39′	85° 15′	253	120	1002	3,4	Tampa, Fla.
27° 05′	96° 00′	450	72	1007	3,4	Corpus Christi, Texas
27° 00′	86° 00′	1750	180	1003	4	Tampa, Fla.
24° 16′	84° 35′	1605	185	1002	4	Cape Sable, Texas
24° 04′	81° 37′	475	69	1002	4	Cape Sable, Texas
23° 54′	81° 37′	675	79	1002	3,4	Cape Sable, Texas

[1] Shown on C&GS Chart.

Radioactive

27° 14′	89° 33′	1055	109	1007		South Pass. Miss. Delta, La. (AEC)
25° 40′	85° 17′	1795	190	1007		Cape Romano. Fla. (AEC)

Dredging Spoils

26° 39′	82° 18′	< 3	3	1255		Punta Gorda, Fla. (C&GS)
27° 33′	82° 51′	6	7	1257		St. Petersburg, Fla. (C&GS)
27° 35′	82° 45′	5	1	1257		St. Petersburg, Fla. (C&GS)
27° 46′	82° 47′	< 1	1	1257	2	St. Petersburg, Fla. (C&GS)
27° 58′	82° 50′	< 1	1	1257	2	Clearwater, Fla. (C&GS)
28° 07′	82° 49′	< 1	1-3	1257	2	Tarpon Springs, Fla. (C&GS)
28° 58′	82° 50′	< 3	1-7	1259	2	Yankeetown, Fla. (C&GS)
29° 08′	83° 05′	< 3	1-2	1259	2	Cedar Keys, Fla. (C&GS)
29° 12′	83° 05′	< 1	1-2	1259	2	Hog. Is., Fla. (C&GS)

Gulf Coast Disposal Areas–(Cont.)

Latitude North	Longitude West	Depth Fathoms	Distance N. Miles	Chart Source	Note	Comment
29° 16′	83° 08′	<1	1-2	1259	2	Hog. Is., Fla. (C&GS)
29° 18′	83° 11′	<1	1-2	1259	2	Hog. Is., Fla. (C&GS)
29° 25′	83° 17′	<1	1-2	1260	2	Horseshoe Beach, Fla. (C&GS)
30° 03′	84° 11′	<1	1-3	1261	2	St. Marks, Fla. (C&GS)
29° 54′	84° 31′	<1	1-3	1261	2	St. James Is., Fla. (C&GS)
29° 53′	85° 32′	8	7	1263		Port St. Joe, Fla. (CE)
29° 50′	85° 30′	7	7	1263		Port St. Joe, Fla. (CE)
30° 23′	86° 31′	<1	1	1264	1	Valparaiso, Fla. (C&GS)
30° 17′	87° 19′	4	2	1265	3	Pensacola, Fla. (C&GS)
30° 16′	87° 20′	6	3	1265		Pensacola, Fla. (CE)
30° 09′	88° 06′	7	4	1266		Mobile, Ala. (CE)
30° 16′	88° 16′	<1	5	1267	2	Bayou La Batre, La. (C&GS)
30° 21′	88° 17′	<1	1-3	1267	2	Bayou La Batre, La. (C&GS)
30° 17′	88° 33′	<1	1-4	1267	2	Pascagoula, Miss. (C&GS)
30° 12′	88° 37′	7	5	1267		Pascagoula, Miss. (CE)
30° 20′	88° 47′	<1	1-3	1267	2	Biloxi, Miss. (C&GS)
30° 18′	89° 03′	<1	1-5	1267	2	Gulfport, Miss. (C&GS)
30° 10′	88° 54′	4	14	1267		Gulfport, Miss. (CE)
30° 10′	88° 59′	5	14	1267		Gulfport, Miss. (CE)
30° 10′	89° 32′	<1	1	1268	2	Pearl River Is., Miss. (C&GS)
30° 10′	89° 21′	<1	4	1268	2	Pearl River, Miss. (C&GS)
30° 08′	89° 33′	<1	1	1268	2	Pearl River Is., Miss. (C&GS)
29° 32′	89° 11′	<1	1-21	1270	2	Miss.-Gulf Outlet Canal, La. (C&GS)
28° 52′	89° 31′	32	5	1272		SW Pass, Miss., River Delta, La. (CE)
29° 03′	88° 58′	35	6	1272		SE Pass, Miss. River Delta, La. (CE)
29° 15′	89° 36′	<1	1	1273	2	Pelican Is., La. (C&GS)
29° 17′	89° 41′	<1	1	1273	2	Grand Bayou Pass, La. (C&GS)
29° 15′	89° 55′	<1	2	1273		Barataria Pass, La (C&GS)
29° 17′	91° 27′	<1	1-16	1276	2	Atchafalya Bay, La. (C&GS)
29° 43′	92° 06′	<1	1	1277	2	Mud Point Bay, Vermilion Bay, La. (C&GS)
29° 30′	92° 19′	<1	2	1277	2	Freshwater Canal, La. (C&GS)
29° 42′	93° 21′	<3	7	1278		Calcasieu Pass, La. C. (CE)
29° 42′	93° 20′	<3	7	1278		Calcasieu Pass, La. (C&GS)
29° 45′	93° 20′	<1	1	1278		Calcasieu Pass, La., A (CE)
29° 45′	93° 20′	<1	1	1278		Calcasieu Pass, La., B (CE)
29° 35′	93° 17′	<3	14	1278		Calcasieu Pass, La., D (CE)
29° 27′	93° 42′	<5	15	1279		Sabine, Texas, E (CE)
29° 30′	93° 45′	<5	11	1279		Sabine, Texas, D (CE)
29° 33′	93° 49′	<5	7	1279		Sabine, Texas, C (CE)
29° 37′	93° 50′	4	3	1279		Sabine, Texas, A (CE)
29° 37′	93° 48′	5	3	1279		Sabine Texas, B (CE)
29° 40′	93° 51′	2	1	1279		Sabine, Texas (C&GS)
29° 04′	94° 35′	9	21	1282	3	Galveston, Texas (C&GS)
29° 17′	94° 40′	6	7	1282		Galveston, Texas C (CE)
29° 20′	94° 40′	5	5	1282		Galveston, Texas, B (CE)
29° 19′	94° 40′	6	5	1282		Galveston, Texas, A (CE)
29° 22′	94° 43′	2	1	1282		Galveston, Texas (C&GS)
28° 55′	95° 17′	<3	1	1283		Freeport, Texas, A (CE)
28° 55′	95° 17′	<3	1	1283		Freeport, Texas, B (CE)
28° 54′	95° 16′	<3	1	1283		Freeport, Texas, C (CE)
28° 24′	96° 18′	<3	2	1284		Port Lavaca, Texas (CE)
27° 49′	97° 01′	5	3	1286		Corpus Christi, Texas (CE)
36° 34′	97° 15′	6	1	1287	1	Port Mansfield, Texas (CE)
26° 04′	97° 07′	9	2	1288		Brownsville, Texas (CE)

APPENDIX C.

THE MARINE ENVIRONMENT AND SOLID WASTES

This appendix is a review and summary of physical, chemical, geological, and biological oceanographic principles and processes and is intended as an introduction to the marine environment for the nonspecialist. The emphasis is on the relationships and processes most directly related to behavior of solid and liquid wastes discharged at sea.

PHYSICAL OCEANOGRAPHY

Physical oceanography is that branch of oceanography concerned with the description and interpretation of the physical state of the sea and its variations in space and time, and of the physical processes occurring in the sea This science deals with water masses and how they are formed, the major current systems dispersing and mixing these masses, and the motions and interactions of oceanic energies. It also includes the study and prediction of temperature, tides, currents, and waves.

Various types of currents may transport waste materials laterally in the water column over great distances, as well as moving materials which have settled to the bottom. Of special significance with respect to waste liquids and sludges is the process of mixing in which dissimilar liquids diffuse into each other–the mixing rate determines how rapidly a waste will be diluted.

Waters of the oceans are typically characterized by their temperature, salinity, and density so that oceanographers can identify both the sources of the water masses and the degree of mixing. A brief discussion of these properties is necessary before considering the ocean's dynamic processes such as currents and mixing.

Distribution of Temperature, Salinity, and Density

Water temperature and salinity are two of the basic physical properties used to measure and describe the processes and circulation of the sea. Density, the third basic property, is a nonlinear function of temperature, salinity, and pressure, and thus changes in these three properties result in changes in water density.

Sea temperature has been measured for centuries and is relatively easy to determine. It varies with time, depth, latitude, incoming radiation and, as discovered more recently, may be subject to variations at some depths because of internal waves. In a very general way, the ocean can be considered a three-layer system: the thin, warm surface layer which is isothermal in the winter; the main thermocline separating a transition layer about 1,500 to 3,000 feet thick where the temperature drops from about 17 C to 5 C, and underlying nearly homogenous cold, deep water extending to the bottom. During summer months, warming tends to develop stratification in the surface layer, but little seasonal effect penetrates below 600 to 900 feet.

Salinity, generally speaking, refers to the total concentration of dissolved solids in the ocean? it increases with depth and varies with time, latidude, and to some extent with local mixing. Variations in salinity (and in temperature) generally occur in the upper layers of the sea and decrease with depth. Temperature and salinity data are usually plotted on a T-S curve (Figure 22) as developed by Helland-Hanson.[1]

Density of seawater is defined as the mass per unit volume expressed in grams per cubic centimeter. Variations in density are a function of variations in

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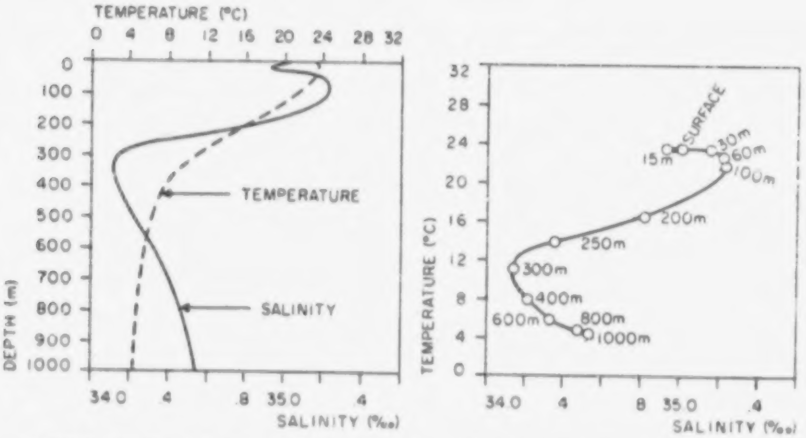


FIGURE 22. The left diagram illustrates the variation of temperature and salinity with depths for an area in the vicinity of the Hawaiian Islands. The T-S curve (right diagram) illustrates temperature vs. salinity in profile with depth. This curve identifies a water mass which helps in tracing the origins of distinct layers. (From Williams.[3])

temperature, salinity, and pressure, and values typically range from 1 for freshwater to 1.07 for the greatest depths. The vertical stability of the sea is due to the increase of density with depth. Calculations of density are made indirectly through measurement of temperature, salinity, and pressure (depth). Through the determination of layers of equal potential densities, calculations of water circulation are possible since water moves along these surfaces.

Water Masses

The term "water mass" refers to a more or less discrete body of ocean water defined on the basis of its physical and chemical characteristics, most typically expressed in terms of temperature-salinity relationships. A water mass thus indentified can be traced from its source area as it moves into adjacent oceanic areas. Subsurface water masses form because surface water in a given area becomes dense enough through evaporation or cooling to sink and spread in layers according to their densities.

A water mass is usually made up of several water types, which are represented by single temperature-salinity values. There are many different water masses in the ocean, but in general they may be grouped into five major categories: surface or near surface water (maximum depth approximately 900 feet), central water (900 to 1,500 feet), intermediate water (1,500 to 3,000 feet), deep water (3,000 to 12,000 feet), and bottom water. Within the five broad categories, there are over 23 major water masses known.[3]

Discharges of large volumes of waste materials in a given area may produce a small water mass whose characteristics could be used to describe the ultimate fate of the wastes. For example, off the New York City area the local effect of acid waste disposal on water color, pH and salinity are identifiable and provide a means of tracing the wastes.

Ocean Currents

Both the nearshore local currents and the permanent major ocean currents are likely to play a role in the ultimate distribution of finer or lighter fractions of such wastes as dredge spoil and industrial chemicals once discharged at sea. Because local currents are somewhat stronger, they may be important in carrying materials from the disposal site into shallower or deeper water. Deeper currents offshore at mid-depths can move suspended materials and thus prevent them from reaching the intended sea floor site. Recently collected evidence from great depths using bottom photographs of ripple marks, scouring, and absence of few sediments on high points, has shown that bottom currents have sufficient strength to move sizable particles and thus shift comparable waste solids discharged into the particular site.

The major circulation of the oceans involves large-scale currents of a permanent nature, such as the Kuroshio, Gulf Stream, and Equatorial Currents. The driving force for these currents is caused primarily by differences in density. In this type of water flow, the effect of the earth's rotation, called Coriolis force, is also a significant factor that causes a deflection of the currents. The nonpermanent currents, which are more localized, are related to winds, tides, and waves. Sverdrup, Johnson, and Fleming as well as Johnson have discussed the following types of currents in the oceans: currents related to the distribution of density in the sea, currents induced by wind stress, tidal currents and those associated with internal waves, currents of new transport induced by surface gravity waves, and boundary currents associated with freshwater.[3,4]

Density Currents. Density currents develop because of differences in water density over horizontal distances where water tends to move down a density gradient. By measuring a vertical profile of temperature, salinity, and pressure at many ocean stations, the calculated densities provide the basis for dynamic computations that show the field of relative motion in a fluid. This technique is known as the geostrophic method and gives a broad picture of the total steady-state ocean circulation. Measurements by current meters, drogues, and neutrally buoyant sonar floats have confirmed some of these calculations.[5] Further, although direct measurements of current at sea are difficult and time consuming, such measurements have resulted in some discoveries such as finding counter-currents flowing in the opposite direction below many of the major currents. The existence of such counter currents was not indicated by geostrophic calculations, which had satisfactorily defined ocean circulation patterns.

Wind Stress Currents. When winds blow over the sea surface a stress is exerted that causes wind drift of a thin layer of surface water. This transport in turn tends to alter the density distribution and may lead to the formation of density currents as described above. In 1902, Eckman made theoretical calculations and experiments that showed that a current induced by a surface wind would decrease with depth to a point where the frictional forces would become negligible.In developing the concept of the Eckman Spiral effect (Figure 23), he concluded that because of Coriolis effect (the apparent deflecting force resulting from the earth's rotation) in the Northern Hemisphere the wind-blown surface waters move at 45 degrees to the right of the wind direction. As the current velocity decreased with depth, the current direction deflected progressively to the right, so that at a particular depth the mass transport would be at right angles to the wind direction. Experiments have shown that actual wind drift was 3 to 5 percent of the wind velocity and from 30 to 60 degrees of wind direction. The magnitude of those wind stress currents depends on wind speed and duration. Current velocities range from 005 knots to 2 knots.[7]

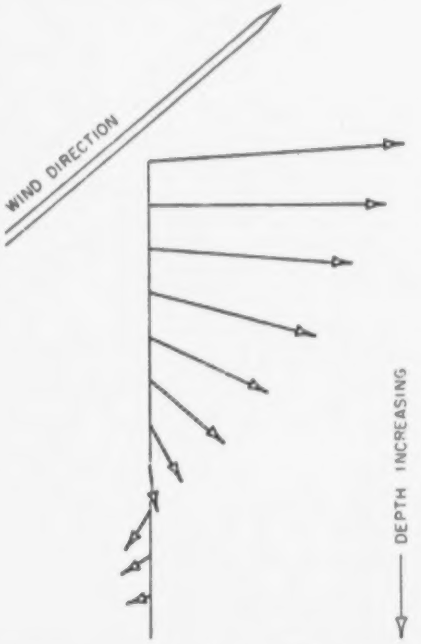


FIGURE 23. The Ekman Spiral showing the effect of surface winds on drift currents. Because of Coriolis force, the net mass transport is 90 degrees to the right of the wind direction in the Northern Hemisphere. The length of the arrows represent current velocities, which decrease with depth as a result of friction.[6]

Near coasts this mass transport of water at right angles to the wind direction becomes extremely important (for example, along the coasts of California and Peru). In both cases, warmer, lighter nearshore water is moved away at right angles from the coast, and colder, deep water is drawn up in the process known as upwelling. Valuable nutrients are brought to the surface during the summer months aiding in the productivity of fisheries. Upwelling is also a possible mechanism which could bring dissolved traces of wastes originally discharged in deep water back to the near surface waters where man's activities are concentrated. Examples of upwelling have been discussed by La Fond.[8]

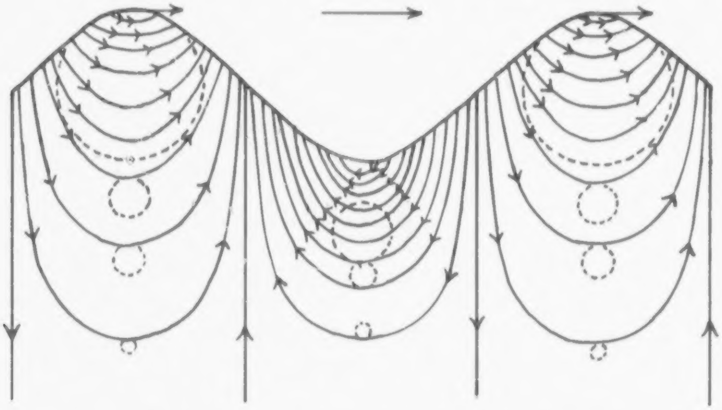
Tidal Currents. Currents caused by the astronomical forces of the moon and the sun can be extremely strong in certain restricted areas, but for the most part these currents do not bring about the transport of water over large distances. Strong tidal currents move large volumes of sediment along the bottom, although because of alternating directions of the ebb and flood, the net transport is small. Such currents may have important effects on some nearshore disposal grounds by thorough repeated frequent stirring, mixing and winnowing of the wastes.[9,10]

In the open ocean, tidal currents generally are rotational either on a 12–(semidiurnal) or a 24-hour (diurnal) basis with rotational effects depending on Coriolis force. Theoretically, according to Sverdrup, the tidal current runs in the same direction and with the same velocity from surface to bottom.[3] Actually, this holds true only in shallow water to about 60 to 90 feet off the bottom. In coastal areas, tidal velocities up to several knots are reported. In an area such as San Francisco Bay, tidal currents approaching 5 knots on the surface with 3 knots along the bottom have been observed.[11]; while in Cook Inlet, Alaska, where tides are higher, currents may be about 8 knots or more.

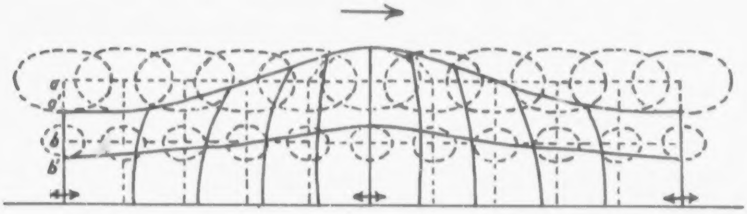
Associated with tidal currents is the occurrence of internal waves, which are subsurface waves found between layers of different density as described by LaFond.[19] In deep water these waves may be several hundred feet in height and could be responsible for considerable water mixing and transport, although it has been difficult to measure effects from these waves. Velocities resulting from internal waves may be sufficient to prevent sediment deposition on topographic prominences on the sea floor.

Wave-Induced Currents. Surface gravity waves caused by wind stresses have an advancing orbital motion that produces a small net drift or wave drift of water masses in the direction of wave advance.

Surface waves in deep water have an orbital motion, which decreases with depth, while in shallow water, the motion becomes elliptical and, at the bottom, oscillatory (Figure 24).[12] Oscillatory currents on the bottom become significant at depths less than half the wave lengths. These cause sediment ripples and sorting at depths up to 600 feet.



Streamlines and orbits in a wave traveling to the right in deep water.



Orbital motion and positions of water filaments in a progressive wave traveling to the right in shallow water.

FIGURE 24. Orbital motion in waves, after Defant.[12]

Currents resulting from wave action in the surf zone occur when waves breaking at an angle to the shore induce a longshore current, or littoral drift. This current forms parallel to the beach and proceeds until a natural break, or passage, occurs allowing return of the water in a rip current. Both of these wave-induced currents are very local, but in times of large storm waves they can be responsible for nearshore movement of large amounts of sediment or waste materials.

Turbidity Currents. When sediment is suspended in water, the combination is denser than water and this mixture will flow downslope;classic laboratory experiments carried out in 1950 by Kuenen show the nature of such turbidity currents.[13] In the past, these currents were believed to be a major cause in the erosive formation of submarine canyons that extend across many of the continental shelves of the world.[14] Shepard pointed out that few, if any, turbidity currents have ever been observed or measured, but it is certain that such currents exist.[11] Recent evidence presented by Shepard and Dill indicated that although turbidity currents are unlikely explanations for the erosive formation of submarine canyons, they may move large volumes of sediment out through these canyons.[15] According to Shepard, probable velocities in turbidity currents are not greater than those found in lower reaches of rivers. These have been reported by Leopold and Maddock to be generally between 2 and 10 feet per second.[16]

From the standpoint of marine waste disposal, it is possible that the introduction of high density sludges and chemicals could initiate a turbidity current and carry a slurry of the sediment and waste mixture away from the disposal area and far out to sea.

Some Observations of Bottom Currents. Although bottom currents are known to operate in both shallow and deep water, relatively few *in situ* measurements have been made. This is primarily because in the past, instrumentation was inadequate. Shepard mentioned reports of strong bottom currents associated with topographic highs in the Gulf of Mexico.[11] Photographs of seamount tops disclose absence of sediment, or evidence of current motion in depths greater than 6,000 feet. Off the east coast of the U.S., deep-current measurement have shown maximum velocities of 0.8 knots at 12,000 feet, although most observations indicate velocities far lower.[17,18] Observations from deep submersibles have given reliable current measurements. LaFond indicated velocities of 0.1 to 0.2 knots at depths of 3,000 to 3,500 feet.[19] There appeared to be no limiting depth to bottom currents in photographs by Cousteau showing a scoured, bare rock bottom in 23,000 feet. Ripple marks are made by currents at 16,000 feet (Figure 25). The observations of Piccard and Dietz in Dive 70 of Trieste I confirmed the presence of life requiring oxygen at the greatest depth of any trench (35,590 feet), thus indicating some kind of circulation to provide oxygen at these depths.[21]

Importance of Currents in Dispersion of Solids

As more direct current observations are made, it is apparent that mid-water and bottom circulation occurs in many more areas and deeper than was once thought. Strong current action along the continental shelf can move sizable particles (as described in the next section). Further, the somewhat slower circulation in deeper areas of water over the bottom can be important as a dilution factor. The movement and dispersion of dissolved materials (including any wastes which are present) are controlled by the water circulation in any adjacent to the disposal site and the natural turbulent mixing processes in the sea. Along the beaches, or littoral areas, and on most of the continental shelf, a mixture of tidal and wind currents with some wave-induced effects will be the most important forces. Off the shelf and down the continental slope, currents become noticeably weaker with occasional turbity current action in submarine canyons. Finally, at great depths currents appear to move fine grained sediment but are less understood as to origin, duration, or measured velocity.

Stirring and Mixing

In looking at the effect of stirring and mixing of two fluids, Eckart uses as an example an experiment which mixes coffee and cream.[23] There are three distinct observable stages that are analoguous to the introduction of one fluid of differing density into another (or of a sludge or chemical into the sea). These three stages are: (1) an initial stage in which rather large volumes of the different fluids are distinctly visible with sharp gradients at the interfaces. If no motion is induced, the boundaries persist for some time; (2) an intermediate stage that continues after stirring of the two liquids, is induced. The contrasting masses of fluid are distorted, increasing the extent of the interfacial areas having high concentra-

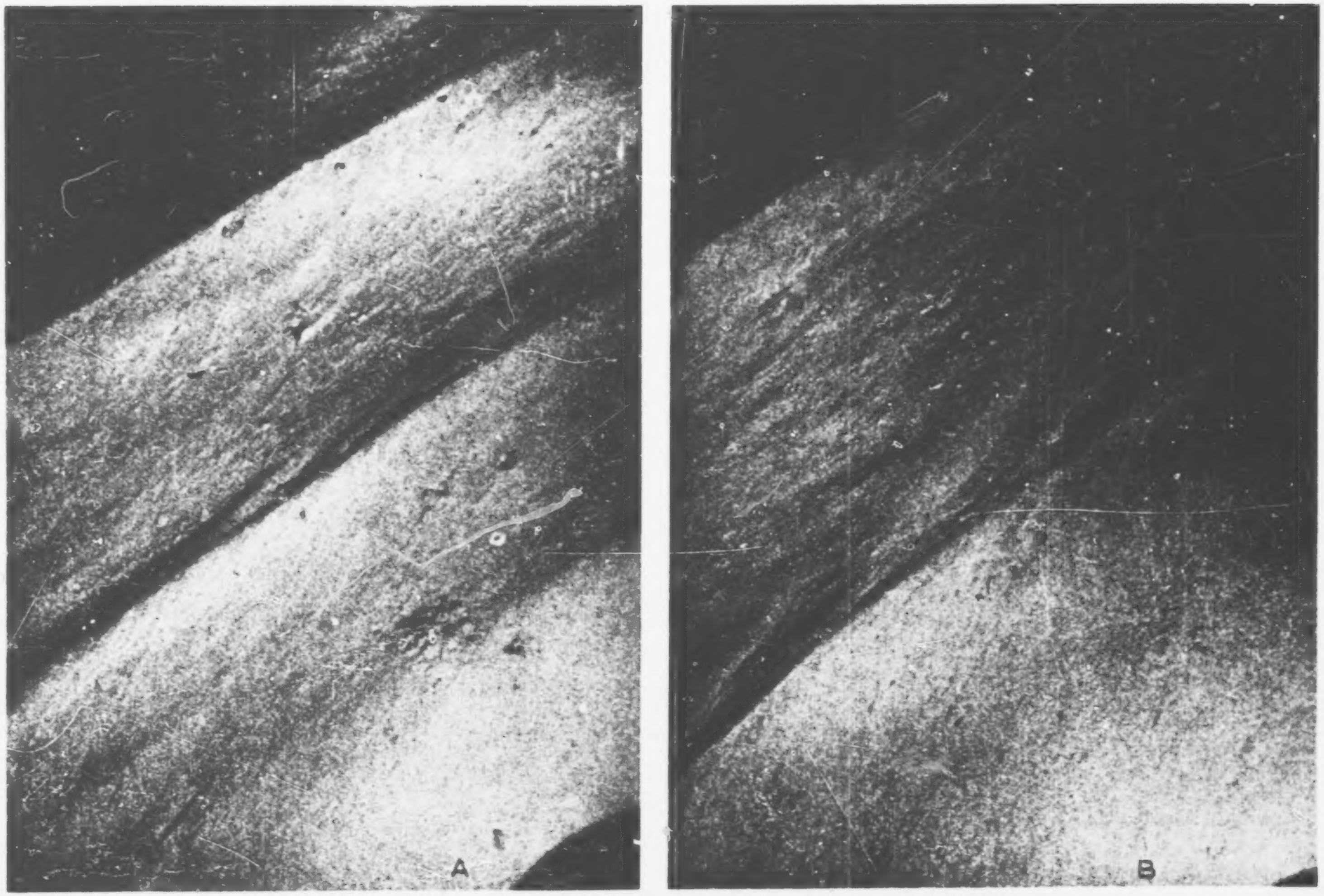


FIGURE 25. Well developed longitudinal ripple marks showing bottom currents photographed at 4,900 m (16,000 feet) in the Indian Ocean. The current flow here is parallel to the crests and lineations show currents moving from lower left to upper right. (From Heezen and Hollister.[18])

tion gradients; (3) the final stage in which the gradients disappear quite suddenly, and the liquids become homogenous. This stage is usually referred to as mixing (to distinguish it from stirring); according to Eckart, this is presumably caused by diffusion. Thus, it is likely that after the introduction of one fluid into another, the two may show distinct boundaries which persist until stirring motions change the average gradients and mixing results.

GEOLOGICAL OCEANOGRAPHY

Geological oceanography, sometimes called submarine geology or marine geology, is that branch of the science that includes the study of coasts and shorelines; the continental shelf (the broad platform surrounding most coasts); the continental slope leading from the shelf edge down to the deep ocean; and the deep ocean floor with its occasional basins and trenches. It also considers the nature and origin of sea floor topography and sediments and includes geophysical studies that provide information about the earth's crustal structure beneath the sea floor.

By examining the regions bordering our continents, we can understand the physical description of areas where waste materials are now being discharged, or will be in the future. Further, we find that the same forces that act on natural sediments, either those derived from land or the ocean, act equally on many waste materials, particularly sludges and dredge spoil. Thus, bottom currents that can suspend and transport sand grains, will move equivalent size particles of waste material.

Continental Borders

In the world ocean, the continental land masses are fringed by shallow continental shelves of varying width. At their outer edges the shelves steepen abruptly into the continental slope that extends down to the deep ocean floor. These features and the basins and trenches, which mark the ocean floor and constitute its major bathymetric divisions, have characteristic depths and areas Table 10) (Figure 26).

The geologic development of the edges of the continents is complex and involves a combination of repeated sea-level changes and sedimentation processes that have built the continental shelves. The geologic development of the ocean floor with its deep basins and trenches is probably even more complex and includes possible drift of the continental masses associated with sea floor spreading and build-up of major ranges of submarine volcanic mountains.

TABLE 10
DEPTH AND AREAS OF MAJOR
BATHYMETRIC OCEAN DIVISIONS

	Depth (feet)	Total ocean area (%)
Continental shelf	0 – 600	7
Continental slope	600 – 3,000	13
Deep ocean	3,000 – 18,000	80
Ocean basins and trenches	18,000 – 35,000	1

Continental Shelf

The shallow platform surrounding the continents forms the continental shelf which comprises 18 percent of the land area and 7 percent of the ocean's total area. The shelf generally terminates seaward with a distinct increase in slope called the shelf-break or shelf-edge. As a matter of convenience and because early navigation charts only showed 10, 100, and 1,000 fathoms, the figures of 100 fathoms (600 feet) historically was the definition of the shelf edge.[24] Most workers agree that shelves can vary in edge depth from 60 to 1,800 feet with a world average of 430 feet.

The average bottom gradient for all shelves is 12 feet per mile (or an angle of seven minutes), which is a slope less than the human eye can detect. The width of continental shelves varies markedly, ranging from zero to 750 miles, with an average width of 44 miles. The shelf off the east coast of the United States ranges in width from a mile or two at Miami to over 200 miles off Newfoundland. On the west coast, it varies from 2 to 15 miles. Detailed information is available on the topography of most of the world shelf, but similar detailed data on the nature and extent of the sediment cover is known for only about one quarter of this area. The geologic structure and bedrock relationships are known for less than 10 percent of the shelf area. In general, the continental shelves may be viewed as depositional environments where sediments eroded from the continents over millions and millions of years have been built-up in enormous volumes.

Emery has classified the continental shelf into six types on the basis of origin.[24] These are: (1) tectonic dams—formed by geological uplift or lava overflow as on the west coast of North and South America; (2)

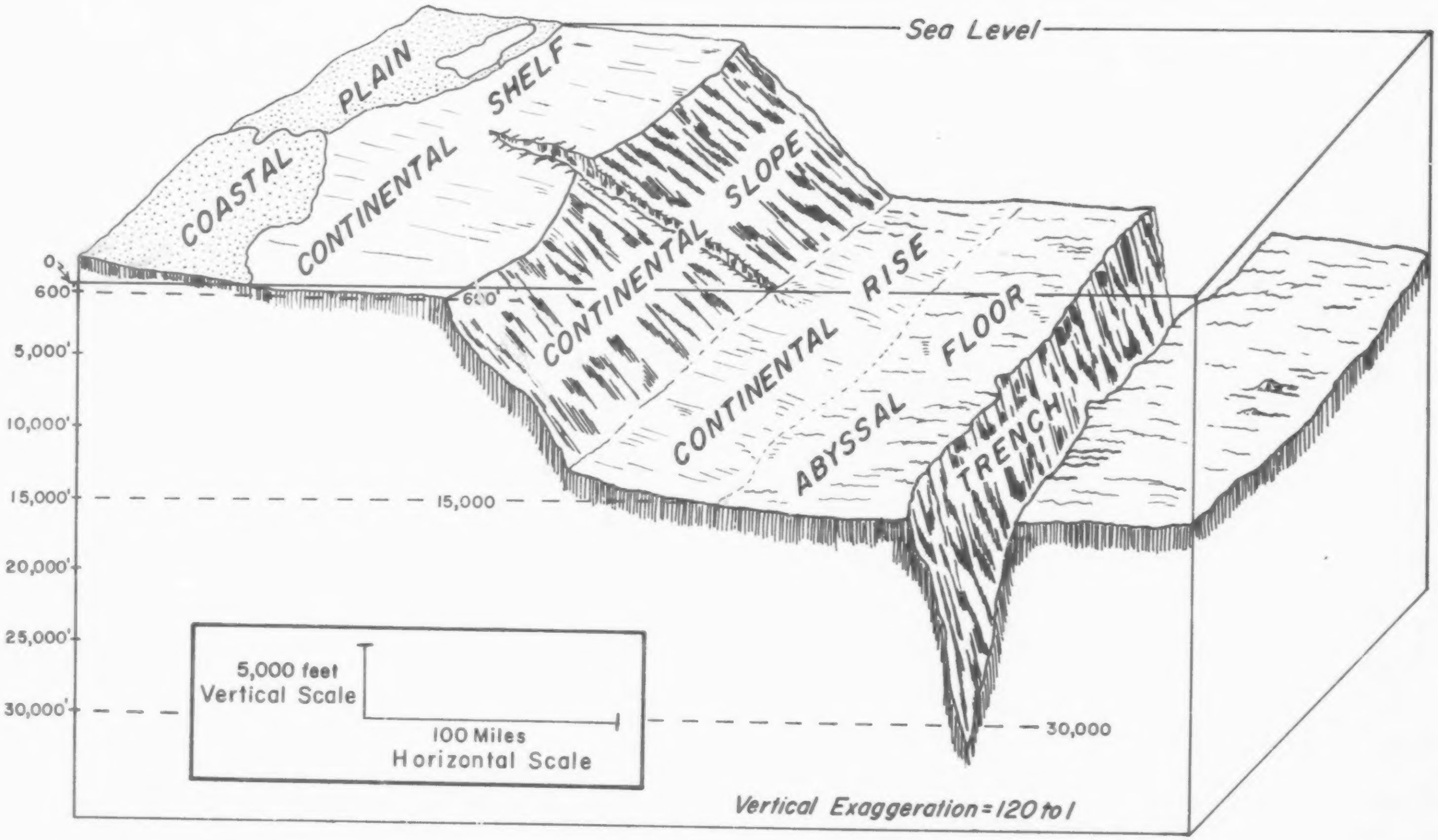

Sea Level
COASTAL PLAIN
CONTINENTAL SHELF
CONTINENTAL SLOPE
CONTINENTAL RISE
ABYSSAL FLOOR
TRENCH
0
600
5,000'
10,000'
15,000'
20,000'
25,000'
30,000'
600'
15,000
30,000
5,000 feet
Vertical Scale
100 Miles
Horizontal Scale
Vertical Exaggeration = 120 to 1

FIGURE 26. Block diagram illustrating relationship of major continental border and oceanic features. Note large vertical exaggeration. The Continental Shelf actually averages less than one degree gradient, the Slope about 4 degrees, and the Rise somewhat less.

reef dams–created by marine organisms, as in the Carribbean; (3) the Diapir dam–formed by salt domes damming sediments, in the West Gulf of Mexico; (4) no dams–simply sediment layers, such as most of U.S. East Coast; (5) ice-eroded–ice erodes any of the above, as in the Arctic and Antarctic; (6) wave-eroded–waves erode any of the above, as on the west coast of North and South America.

Continental Slope

The continental slope is the important transition zone between the two general levels of the earth's surface; namely, the continental surface, which more or less approximates sea level, and the vast ocean floor, which averages about 13,000 feet below sea level. The upper border of the continental slope begins at the shelf break; the lower limit is less clearcut because the slope grades into the surface of the deep ocean floor. The average gradient for the continental slope has been estimated as on the order of 4 to 5 degrees (about 400 to 500 feet per mile), but slope gradients as steep as 45 degrees may occur, and 25 degrees may be common.[11,25] Slope gradients vary by region; the Pacific Coast slopes are steeper than the Atlantic Coast. About half the slopes terminate in bordering trenches and depressions, while the rest end in sediment fans, or a rise. Shepard has recommended that this lower region where it approaches the deep ocean floor be called the continental rise.[11] The general width of all continental slopes is 10 to 20 miles disregarding the rise, which would considerably extend the width.

Continental slopes can be irregular in profile and have such features as hills and basins, plateaus and terraces. With respect to the sediment cover, structure, and bathymetry much less is known about the continental slope than for the shelf.

Structurally, the crustal material beneath the continental slope thins from the continental to the oceanic crust. As with the continental shelves, the slopes do not all appear to have the same origin. Possible causes for the formation of slopes include; wave-built terraces, deltaic beds, down-warped continental sediments, and fault zones.[11]

Submarine Canyons. These canyons are certainly the most distinctive topographic features on the shelf and slope. Shepard and Dill have examined the canyons throughout the world ocean, concluding that they are not all of one origin, but likely result from several causes.[15] They have classified the canyons into five types: (1) V-shaped valleys with winding courses and dendritic tributaries; (2) straight-walled, trough-shaped valleys, cut with unconsolidated sediments; (3) winding valleys with tributaries cut into sediment fans on slopes; (4) valleys, which run along faults and commonly parallel the coast; (5) continental shelf valleys not extending to slopes. It is interesting that these canyons function as channels that funnel large sedimentary loads from nearshore areas downslope into deep water.

Deep Ocean

The Deep Ocean is usually classified as extending to 18,000 feet and covering 80 percent or the greatest part of the total ocean floor. This provinces within it are the abyssal hills, which stick up through layers of sediment of varying thickness, and the abyssal plains, a generally smooth, featureless floor with low slopes. The plains usually begin at the base of the continental rise and extend seaward into the hills.[26]

Trenches

Although trenches and basins make up only about 1 percent of the total ocean area, the trenches form exceptionally striking features in the floor of the Pacific Ocean and to lesser extent in other oceans. More than 10 major trenches exist in the Pacific, 2 with depths to 35,590 feet. Piccard and Dietz described echo-sounding bathymetric surveys and manned submersible exploration of several of these[21] According to Shepard, trenches have narrow, flat floors several miles wide, generally composed of diatom ooze and gravel.[11] The deepest Pacific trenches are located along the west margin of the Pacific Basin and are associated with the arc-shaped chains of islands such as the Aleutians, Kuriles, and Marianas where earthquakes are frequent. Trenches generally contain some benthic organisms, but have a relatively low modified density.

Sedimentology

The sedimentary materials normally entering the sea from the land, as well as those originating in the sea, are highly varied and include: detrital material from land, sub-aerial or submarine volcanic products, organic and skeletal matter, inorganic precipitates, products from chemical reactions, and extraterrestrial materials. These input materials result in four basic types of bottom sediment: (1) pelagic sediments (organic ooze); (2) terrigenous sediments (silt and clay); (3) marine glacial sediments (sand and gravel); (4) volcanic sediments (ashes and pumice).

The behavior of several types of solid waste materials discharged at sea is nearly identical with that of sediment particles carried to the sea or precipitated in the water column. These particles settle at calculable rates dependent on water characteristics and on the properties of the particle. These computations allow a general determination of the amounts of a given material that should reach the sea floor more or less immediately, or should remain in suspension for a long time. An understanding of the marine conditions governing sea floor erosion, transportation, and deposition is important in order to appreciate what forces may effect solid waste materials.

Deposition, Transportation, and Erosion. The sedimentary debris that has been transported to the sea settles through the water column, at the same time being carried laterally by the effect of currents. The settling velocity of a sedimentary particle depends upon the specific gravity, size and shape of the particle, as well as the viscosity and specific gravity of the water. This relationship is defined in Stokes' law, which states that the settling velocity varies in direction proportion to the square of the particle diameter.[27]

Most of the fine materials (silt, clay and colloid–size particles) are affected by ocean currents during settling; their effective settling velocities probably range from 3 feet per day to many thousand feet per day. In the absence of currents, a particle measuring 4 microns (or coarse clay) settles at a rate of 3 feet per day,[3] and in deep water may be carried about for many years before reaching the bottom. Revelle and Shepard have shown that fine silts and clays may be carried away from shore by large-scale horizontal eddies, such as those occurring off the Southern California coast; they estimate a settling velocity of 50 feet per day for sediments of these sizes.[28] Resulting rates of sediment accumulation may vary from 0.5 mm per year along some abyssal plains to the relatively slow accumulation of 1 to 10 mm per 1,000 years in red clay deposits of the deep ocean.[29]

After sediment settles to the bottom, it may be picked up and carried along by currents over great distances before coming permanently to rest. Thus, the presence of sediment types in one locality may not correctly indicate that sediment of this type is actually being deposited there; it could easily have been eroded, transported, and redeposited from another bottom area. The factors operative in this connection are (1) mass movement of unconsolidated sediments by mud flows and slides on slopes; (2) the movement of individual particles by rolling, sliding, and jumping (traction) along as a result of bottom current forces; (3) the effect of turbulence, mixing, and diffusion.[3]

Hjulström has described the relationship of the three processes of deposition, transportation, and erosion, and represented this in a classic series of curves (Figure 27).[30] Study of these curves shows that a particle size of 0.5 mm (medium sand) is most easily eroded and requires a velocity of less than 0.4 knots. For larger particles, measuring perhaps eight mm (equivalent to a small pebble) the required velocity approaches 2 knots. Erosive pick-up of very small particles (such as fine silt measuring 0.01 mm) requires current velocities of more than 1 knot. Sverdrup concluded that velocities required for erosion and transport of particles of 2 to 3 mm only occur along the bottom in shallow waters, while in deeper water currents are only strong enough to transport fine-to-silty sand.[3] Heezenn reported currents near the bottom of up to 0.4 knots east of Cape Cod and southwest of Cape Hatteras.[17] This velocity is sufficient for erosive pickup of medium sand, as well as the transport of all sediment types found on the continental slope and rise.

Erosional and Depositional Features. Such sediment surfaces features as ripple marks and scour marks (similar to ripple marks seen on many beaches) are produced by selective erosion, transport, and deposition of sediment particularly by wave and current forces. In the course of deposition, a series of laminae or layers build up in the sediment: these are termed current bedding structures.

Inman defined a certain threshold velocity for the initial movement of grains as a fluid flows over a sediment bed.[31] As this velocity increases, a few particles lift off the bottom into suspension. As the fluid with particles in suspension forms vortices, the characteristic current ripple marks develop on the sediment surface. These are usually asymmetric in cross section with the long, gentle slope in the upcur-rent direction, and steep slope facing downstream. Thus, ripple marks indicate current direction. Another type of current feature, longitudinal ripples, also indicates current direction; in this case the

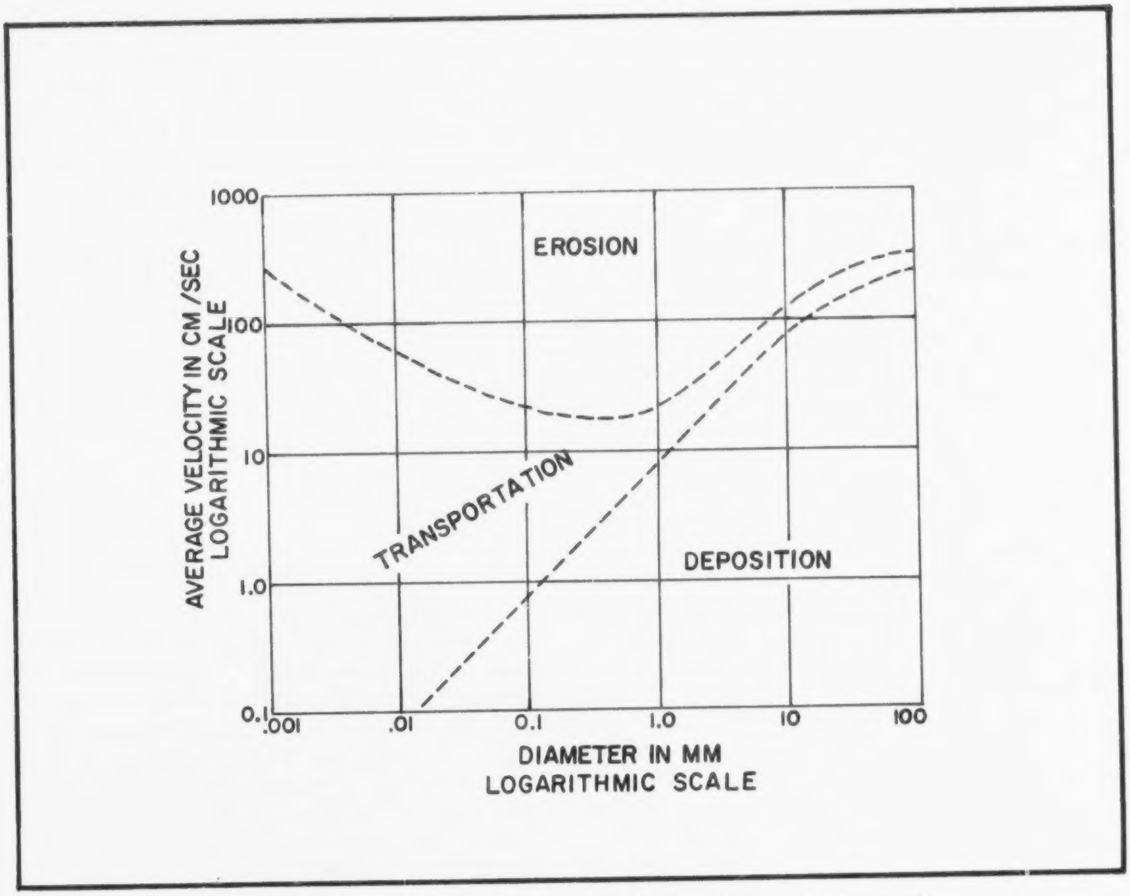


FIGURE 27. Hjulström curves showing approximate regimes for erosion, transportation, and deposition and the relation of particle size to stream velocity. Note that medium sized sediments (sands) are more easily eroded and transported than fine clays or coarse cobbles (see reference 30).

current parallels the crest direction of the much larger symmetrical ripple (Figure 25).

A number of other types of ripples were described by Van Straaten that can also be used to determine flow direction. Further, direct observations of large areas using side-scan sonar equipment have revealed large sand ribbons indicating the one-way sand transport by tidal currents.[33]

Flocculation of Fine Grained Sediments and the Nepheloid Layer. Most marine sediments contain a portion of clay minerals. These form the finest particle size ranging from 4.0 to 0.2 microns (1/200 to 1/4036 mm). The principal clay groups are: kaolinite, montmorillonite, and illite. The chemistry and physics of these complex groups have been described by Grim, and Whitehouse and Jeffery.[34,35] The platelike crystal units of clay tend to stick together, or coagulate in a process called flocculation. Flocculation is enhanced by thee presence of salt water; the rate of flollulation may depend on the salinity. Thus, the fine-grained materials that would settle very slowly in a single-grained condition, according to Stokes' law, tend to settle faster when flocculation occurs.[36]

Within recent years, layers of very fine-grained, suspended sediment have been detected near the bottom in waters several thousand feet deep along the continental slope and rise off the northeastern United States.[37] This layer, measuring 500 to 650 feet thick, has been called the nepheloid layer. Ewing and

Thorndike suggested the layer has its origin in the resuspension of clay-size particles by turbulent flow stirring up the bottom. Gunnerson and Emery reported the occurrence of concentrations of suspended sediment and plankton near the bottom of San Pedro Basin, California.[38] They believed it to be a residual layer formed by a turbidity current, possibly due in turn to internal waves. Observations of a similar layer of suspended materials have been made by deep submersible pilots.[21,39]

Interaction with the benthos. Open ocean or pelagic regions are inhabited by floating (planktonic), or swimming (nektonic) organisms. The bottom or benthic regions are inhabited by sedentary, crawling, or creeping organisms. Among the animals of the benthos are the infauna, which live in the sediments, and the epifauna, which live on the surface or are attached to rocks.

Benthic organisms are involved in a number of sedimentation processes.[3] The larger forms both destroy organic matter as well as ingest sediment causing mechanical abrasion and chemical reactions. In addition, the multitudes of burrowing organisms destroy laminations and related depositional features. Observations from the submersible *Deepstar* confirmed this type of extensive reworking of the upper layers of sediment in the 500- to 2,000-foot-depth range in the Gulf of Mexico.[39] It appears that such reworking may make a significant modification to the surface layers of the lower continental shelf and continental slopes. This reworking by marine animals should also hold true for waste materials overlying or mixed with the sediment.

Areas of Known Marine Geology. The Study of marine geology had its formal beginning with the exploratory work of Sir John Murray, resulting from the voyage of the *HMS Challenger* in the last quarter of the 19th century. Since that time, a great volume of sounding, bathymetry, sediment sampling, and, more recently, geophysical exploration has occurred on worldwide basis. Yet, conservative estimates are that less than 5 percent of the marine geology of the oceans is known at this time. Quite clearly the areas best known are the continental shelves, where there has been greatest activity; in the United States, the entire continental shelf along the east coast, the Gulf of Mexico, and the west coast south of Point Conception are considered in the best known category (Figure 28). The only other areas in a similar category are the shelf areas off Alaska, the British Isles, Southeast Asia, Japan, and a small portion off Venezuela.

The most extensive exploration and mapping of sea floor stratigraphic and structural geologic relationships has been carried out on shelf and upper slope areas by private industry in connection with petroleum exploration and by government agencies. Institutional groups conducting deep ocean work generally have been less interested in precise geologic mapping. Most information from exploratory work by geophysical companies is proprietary and, thus, unavailable for other uses.[24]

In summary, though the continental shelves off the United States are relatively well known geologically, additional detailed investigation of the sedimentation processes operating at each proposed disposal site are necessary in order to forecast the ultimate fate of the waste.

CHEMICAL OCEANOGRAPHY

Chemical oceanography is that branch of the science concerned with the description, interpretation, and prediction of the chemical properties and processes of the sea and their interaction with the physical, biological, and geological processes operative in the marine environment. It involves study of the composition of seawater, and its dissolved gases and nutrients, as well as the use of radiochemical/isotope technology. A comprehensive discussion and review of chemical oceanography has been presented by Hood.[40]

Chemical oceanography and, in particular, an understanding of the various chemical processes operative in the water column and at the bottom are basic essentials in predicting the fate and effects of waste materials discharged in the sea. These processes are closely interrelated with sedimentation processes and the functions of living organisms in the marine environment. Chemical nutrients and the gases in solution are vital to all life in the sea. In this connection, careful study must be given to the various chemical processes that may affect or be affected by marine waste disposal operations.

The chemical properties and relationships in the sea are such that they are not readily susceptible to direct measurement *in situ.* This is due in part to certain constituents occurring in high concentrations and others in extremely low concentrations; thus, the former tend to mask the latter. Further, ordinary laboratory techniques for analysis of water samples

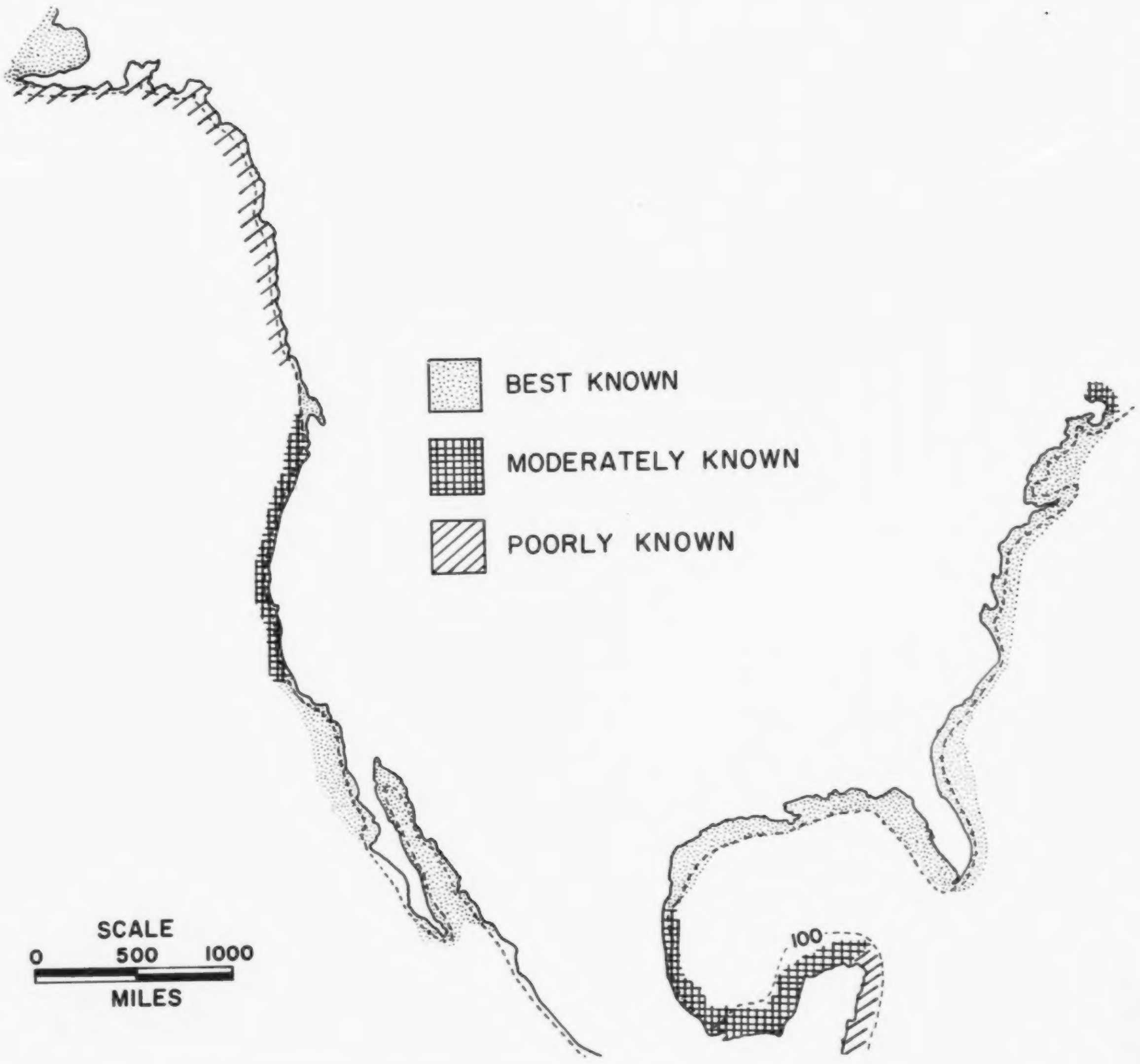

BEST KNOWN
MODERATELY KNOWN
POORLY KNOWN
100
SCALE
0
500
1000
MILES

FIGURE 28. Present state of knowledge of the geology of the continental shelves of United States. Continental shelves underlie 7 percent of the total ocean. The average depth of the shelf edge is 430 feet, and the average width is 44 miles.

are generally inadequate for measuring most of the important but low concentration constituents. In this regard, an acceptably precise technique for the direct measurement of salinity using electrical conductivity was developed only recently. Prior to this development, all such measurements were chemically titrated (a precise measuring technique) and related to standard values for the relationship of the total dissolved solids to the chloride ion concentration.

Factors Affecting Seawater Composition

During the 19th century in an attempt to describe the major constituents of the sea, scientists discovered that the total salt concentration was quite uniform. Dittmar in 1887, after a thorough analysis of 77 sea water samples collected from all over the world by the Challenger Expedition, concluded that the ratio between the more abundant substances was virtually constant. For this reason, the chloride ion is always 55.25 percent of the total dissolved solids. With only minor changes, this relationship—the law of relative proportions—has been proven consistent up to the present.

While the relationship of constituents is consistent on a worldwide basis, local factors have some effect. Thus, snow, ice, rain, evaporation, river runoff, biologic activity, and particulate absorption all have effect in peripheral areas, but the total overall change to the ocean is not measurable.

Major and Minor Constituents. Common table salt makes up over 80 percent of the elements occurring in solution in seawater. The first 10 of these are the major elements, and the remaining are considered minor constituents. The major ones are chlorine, sodium, magnesium, sulfur, calcium, potassium, bromine, carbon, strontium, and boron. The minor elements vary from silicon at 4 mg per Kg to gold at 0.000006 mg per Kg.

Gases in Solution. Atmospheric gases dissolved in the ocean are oxygen, nitrogen, carbon dioxide, argon, helium, and neon; oxygen and carbon dioxide are the most important to the sea and to the life involved. Oxygen is produced by plants in the sea in the photosynthetic process; it also is replenished from the atmosphere in surface exchange. The concentration of oxygen varies from 0 to 9 me per liter (0 to 14 mg per liter). Carbon dioxide, on the other hand, is not dependent on surface exchange as the major source, but it is derived from the carbonate system in the form of bicarbonates of sodium, potassium, and calcium. The phytoplankton tend to use carbon dioxide and the zooplankton or animal life produce it through respiration. In addition, the ph (or acidity) of sea water is closely tied to the carbon dioxide system equilibrium.

Nutrients. Among the substances essential to primary production of phytoplankton are the nutrients, such as phosphates and nitrates. Nutrients are also referred to as the nonconservative solutes. These solutes are present in sea water in low concentrations, but a major fraction of this amount enters and leaves the particulate phase each year. Both the phosphates and nitrates have a cycle of replenishment that is directly related to plant production. The biochemical cycle includes a net downward motion of particulate matter that is essentially balanced by a net upward flux of these constituents in solution as a result of water circulation, particularly by vertical upwelling or by the addition from sources outside the oceans.

Radiochemistry and Isotopes. Radioisotopes have been used to study various phenomena and problems associated with marine waste disposal. For example, the addition of radioactive tracers to wastes such as the effluent from submarine sewer outfalls has assisted in the study of mixing processes. Considerable effort has been given to monitoring the uptake of radioisotopes by living organisms some of which tend to concentrate certain isotopes. Isotopes are also used to study the movement of beach sands and to determine the age of sediments.

Oxidizing Environments

An oxidizing environment is characterized by an oxygen-breathing biologic assemblage living in a relatively oxygen-rich water column and sediment cover on the sea floor. Oxidizing environments are typical conditions of open circulation and, thus, predominate over most of the ocean. Although most near-surface marine sediments are generally in the oxyginated state,[41] nearshore areas with high biological productivity are characterized by anerobic sediments.

In chemical terms, oxidation is a reaction in which electrons are given up. For sea water and sediments, it is generally expressed in terms of electrical potential or Eh. More specifically, Eh is the oxidation-reduction potential (which is also referred to as the REDOX potential). By measuring the electrical potential of sea water or sediments, the state of oxidation can be determined. For sea water, the Eh is positive or, by definition, oxidizing.

Reducing Environments

A reducing environment is characterized by anaerobic or anoxic conditions, that is, conditions without oxygen. These conditions develop when the accumulation of organic matter is so great as to deplete the available oxygen or when the oxygen supply in the water is diminished by other demands. Such conditions generally occur in relatively restricted areas and are indicative of stagnant water found in oceanic basins with limited circulation. Such anaerobic environments usually have high concentrations of hydrogen sulfide and carbon dioxide, and the sediments are typically black muds containing sulphate reducing bacteria.

Chemically, reduction is a reaction in which electrons are taken on. The Eh values for a reducing environment are, by definition, negative.

There are two major types of oceanic basins–the open type, which has outflow over the sill or basin lip; and the closed type with a very shallow sill, which restricts outflow. As would be expected, There are many examples of stagnant basins with shallow sills where all outflow is prevented. The 4,500-foot deep Cariaco Trench off Venezuela is one such basin and has been described by Richards and Vaccaro.[42]

Off Southern California, Emery showed that the bottom water flows between basins in a northwesterly direction.[43] Because variation in sill depths allows sequential flow, most of the basins in this area have sufficient inflow and outflow to maintain oxidizing environments. Emery has calculated that the Santa Barbara basin appears to have a complete exchange of its water mass in about a two-year period.[44]

Even in regions of oxidizing conditions, ZoBell has shown that in many localities samples from a few centimeters below the water-sediment interface show that the sediments contain no free oxygen, and in many cases there is a deficit of oxygen.[45] In the zone of 5 to 10 cm where the bacterial activity is greatest, reducing conditions are typical.

BIOLOGICAL OCEANOGRAPHY

Biological oceanography is that branch of the science concerned with the sea as a biological environment–it is a study of the plants and animals of the sea.

The previous discussion has covered the nature of sea water itself, its physical behavior, the sea floor and sediments, and the chemical constituents. All these factors interact vitally with the ocean[s vast biologic assemblage. Not only does marine life depend on the particular physical and chemical characteristics of sea water, but also on light, depth, pressure, and water movement.

The animal and plant life in the sea can be broadly pictured as two interrelated series of zones: vertical zones, which range from the intertidal to the deep bottom or abyssal zone, and geographic zones ranging from tropical to polar. The reader is referred to Moore's study on marine ecology for a discussion of the progressive biologic variation along these two principal gradients.[46]

Marine Plants

Inasmuch as light for plant growth penetrates sea water only to depths of 600 to 700 feet, only this thin near-surface band (the euphotic zone) can support plant growth. There are two major groups of marine plants: the attached forms and the floating or planktonic forms. The attached forms are concentrated because they must attach to the bottom. These are the blue-green, green, brown, and red algae. The floating or planktonic myriad forms of microscopic primary producers, which serve as feed for the lower animals. Prominent among these are: the diatoms, whose siliceous shells form much of the sediment or diatomaceous ooze on the sea floor; the dinoflagellates, which are important to filter and detritus feeders; and the coccolithophores that are important both as a food and as calcareous contributions to bottom sediments.

In the open ocean, the distribution of phytoplankton communities tends to be patchy and irregular. Areas such as the Sargasso Sea are notably sterile. Phytoplankton occur in greater numbers in coastal waters where there is more nourishment. Concentrations of enormous abundance coincide with those coastal areas characterized by upwelling of nutrient-rich cold water.

Marine Animals

The marine animals range from the microscopic zooplankton to the leviathan mammals such as the whales. The smallest animals, the zooplankton, are floating forms unable to propell themselves against currents. There are two distinct types: the holoplankton, which spend their entire life in the plankton community, and the meroplankton, which are larval forms of larger animals that leave the plankton group at maturity. Probably the two most populous members of the holoplankton group of zooplankton are the copepods and euphausids, which feed on the phytoplankton and in turn are the basic food for larger animals. The zooplankton do not move horizontally any great distance, but some species migrate vertically in a diurnal cycle moving from a depth of roughly 1,000 feet during the day to the surface at night.

At the other end of the scale are the nekton, or free swimmers, which are the most highly specialized group of marine animals and include the vertebrates and some invertebrates. Fish are the largest group among the nekton; they are divided into the sharks and rays (the elasmobranchs) and the true (or bony) fishes (the teleosts). Many of the fish are limited to zones determined by pressure, temperature, and salinity. Depth is probably the greatest limitation and keeps the fish with swim bladders from large vertical migrations. Besides vertical zonation, fish concentrations vary with season, distance from shore, relation to upwelling, and other less understood causes.

Of special interest to the problem of disposal of wastes heavier than sea water is the benthic or bottom community, which includes a number of different phyla of which the most important are sponges (porifera), corals (coelenterata), certain colonial animals (bryozoa), starfish (echinodermata), clams and oysters (mollusca), and lobster and shrimp (arthropoda). These forms exist in varying numbers from shallow to great depths with the littoral zone having the largest benthic population.

Food Chain

The relationships of predator and prey in the ocean is referred to as the food chain or web in which each group feeds on the next lower group, thus making up the many links in the chain (Figure 29). The basic driving force of the web is the sun's radiation, which penetrates the euphotic zones. The plants use this energy along with various nutrients and carbon dioxide in their growth process, and produce oxygen as a byproduct. These plants in the form of phytoplankton are grazed upon by the zooplankton, which in turn are fed on by larger invertebrates, which after many sequential predations become the food of the larger vertebrates. Classically, the efficiency of the web has been given as 10 percent—that is—for every 10,000 grams of phytoplankton, 1,000 grams of zooplankton are fed, and so on, although it has been also suggested that this efficiency may be closer to 15 or 20 percent.

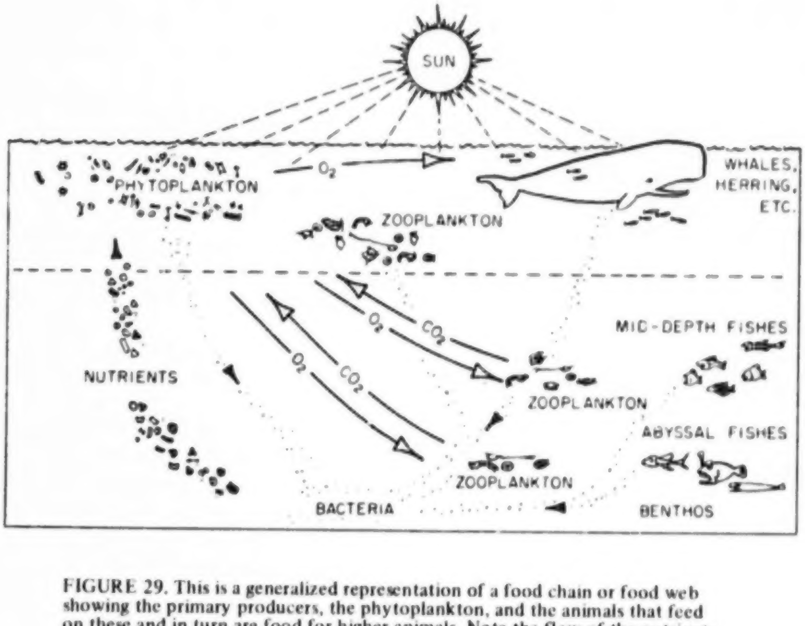


FIGURE 29. This is a generalized representation of a food chain or food web showing the primary producers, the phytoplankton, and the animals that feed on these and in turn are food for higher animals. Note the flow of the nutrients, oxygen, and carbon dioxide as elements of this relationship.[2]

REFERENCES

1. **HELLAND-HANSEN, B.** Nogen hydrografiske metodor skana. Oslo, Naturforsker Mote, Kristiania, 1916.
2. **WILLIAMS, J.** Oceanography; an introduction to the marine sciences. Boston, Little Brown, 1962. 242 p.
3. **SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING.** The oceans; their physics, chemistry, and general biology. Englewood Cliffs, N. J., 1942. 1087 p.
4. **JOHNSON, J. W.** Ocean currents, introduction. *In* Encyclopedia of Oceanography. New York, Reinhold Publishing Corporation, 1966. p. 587-590.
5. **DEFANT, A.** Physical oceanography. v. 1. New York, The Macmillan Company, 1961. 729 p.
6. **EKMAN, V. W.** On the influence of the earth's rotation on ocean-currents. *Arkiv foer Matematik, Astronomi och Fysik,* 2(11):1-52, 1905.
7. **BRETSCHNEIDER, C. L.** On the generation of wind-driven currents over the continental shelf. *In* the new thrust seaward. Transactions of the Third Annual MTS Conference & Exhibit, San Diego, June 5-7, 1967. Washington, Marine Technology Society. p. 97-113.
8. **LaFOND, E. C.** Internal waves. *In* Encyclopedia of oceanography. New York, Reinhold Publishing Corporation, 1966. p. 402-408.
9. **HUME, N. B., R. D. BARGMAN, C. G. GUNNERSON, and C. E. IMEL.** Operation of a 7-mile digested sludge outfall. *American Society of Civil Engineers Transactions.* 126(pt.3): 306-331, 1961.
10. **HUME, N. B., C. G. GUNNERSON, and C. E. IMEL.** Characteristics and effects of hyperion effluent. *Water Pollution Control Federation Journal,* 34(1):15-35, Jan. 1962.
11. **SHEPARD, F. P.** Submarine geology. 2d ed. New York, Harper & Row, Publishers, 1963. 557 p.
12. **DEFANT, A.** Physical oceanography. v. 2. New York, The Macmillan Company, 1961. 598 p.
13. **KUENEN, H.** Marine geology. New York, John Wiley & Sons, Inc., 1950. 568 p.
14. **HEEZEN, B. C.** Corrientes de turbidez del Rio Magdalena, Columbia. [Turbidity currents of the Rio Magdalena, Columbia.] *Boletin de la Sociedad Geografica Colombia,* 14(51 and 52):135-143, 1956.
15. **SHEPARD, F. P., and R. F. DILL.** Submarine canyons and other sea valleys. Chicago, Rand McNalley & Company, 1966. 381 p.
16. **LEOPOLD, L. B., and T. MADDOCK, JR.** The hydraulic geometry of stream channels and some physiographic implications. Geological Survey Professional Paper 252. Washington, U.S. Government Printing Office, 1953. 57 p.
17. **HEEZEN, B. C.** The atlantic continental margin. *In* a coast to coast tectonic study of the United States. *UMR* [University of Missouri at Rolla] *Journal,* No. 1:5-25, 1968. (V. H. McNutt-Geology Department Colloquium Series 1.)
18. **HEEZEN, B. C., and C. HOLLISTER.** Deep-sea current evidence from abyssal sediments. *Marine Geology,* 1:141-174, 1964.
19. **LaFOND, E.** NEW diving log. No. 1, 1966.
20. **COUSTEAU, J. Y.** Calypso explores an undersea canyon. *National Geographic Magazine,* 113(3):373-396, Mar. 1958.
21. **PICCARD, J., and R. S. DIETZ.** Seven miles down. New York, G. P. Putnam's Sons, 1961. 249 p.
22. Reference deleted.
23. **ECKART, C.** An analysis of the stirring and mixing processes in incompressible fluids. *Journal of Marine Research,* 7(3):265-275, 1947.
24. **EMERY, K. O.** The continental shelves. *Scientific American,* 221(3):107-122, Sept. 1969.
25. **TRUMBULL, J.** Continents and ocean basins and their relation to continental shelves and continental slopes. *In* Trumbull, J., J. Lyman, J. F. Pepper, and E. M. Thomasson. An introduction to the geology and mineral resources of the continental shelves of the Americas. *Geological Survey Bulletin 1067.* Washington, U.S. Government Printing Office, 1958. p. 1-26.
26. **HEEZEN, B. C., and M. THARP.** Physiographic diagram of the Indian Ocean. The Geological Society of America, Inc. Abstracts for 1964. Special Papers, No. 82. New York, 1965. p. 88-89.
27. **RUBEY, W. W.** Settling velocities of gravel, sand, and silt particles. *American Journal of Science,* 25:325-338, 1933.
28. **REVELLE, R., and F. P. SHEPARD.** Sediments off the California coast. *In* Trask, P. D., *ed.* Recent marine sediments; a symposium. Tulsa, Okla., American Association of Petroleum Geologists, 1939. p. 245-282.
29. **FAIRBRIDGE, R. W.** Marine sediments. *In* Encyclopedia of oceanography. New York, Reinhold Publishing Corporation, 1966. p. 469-473.

30. HJULSTRÖEM, F. Transportation of detritus by moving water. Part 1. Transportation. *In* Trask, P. D., *ed.* Recent marine sediments; a symposium. Tulsa, Okla., American Association of Petroleum Geologists, 1939, p. 5-31.
31. INMAN, D. L. Ocean waves and associated currents. *In* F. P. Shepard., *ed.* Submarine geology. 2d ed. Chap. 3. New York, Harper & Row, Publishers, 1963. p. 49-81.
32. VAN STRAATEN, L. M. J. U. Rhythm patterns on Dutch North Sea beaches. Overdruk uit, Geol, en Mijnbouw, NS., 15(2):31-43, 1953.
33. BELDERSON, R. H., and N. H. KENYON. Direct illustration of one way sand transport by tidal currents. *Journal of Sedimentary Petrology*, 39(3):1249-1250, Sept. 1969.
34. GRIM, R. E. Clay mineralogy. New York, McGraw-Hill Book Company, Inc., 1953. 384 p. (Shrock, R. R., ed. McGraw-Hill Series in Geology).
35. WHITEHOUSE, U. G., and L. M. Jeffrey. Chemistry of sedimentation. *In* Study of nearshore recent sediments and their environments in the Northern Gulf of Mexico. American Petroleum Institute Research Project 51, 3d Quarterly Report, 1 Jan.-31 Mar. 1953, Report No. 8, Apr. 1953, p. 27-29; 4th Quarterly Report, 1 May-30 June 1953, Report No. 9, July 1953, p. 31-37.
36. GRIPENBERG, S. A study of the sediments of the North Baltic and adjoining seas. *Fennia*, 60(3):1-231, 1934.
37. EWING, M., and E. M. THORNDIKE. Suspended matter in deep ocean water. *Science*, 147(3663):1291-1294, Mar. 12, 1965.
38. GUNNERSON, C. G., and K. O. EMERY. Suspended sediment and plankton over San Pedro Basin, California. *Limnology and Oceanography*, 7(1):14-20, 1962.
39. GAUL, R. O., and W. D. CLARKE. Gulview diving log, May 27-June 12, 1967. College Station, Texas, Gulf Universities Research Corporation, 1968.
40. HOOD, D. W. Chemical oceanography. *In* Barnes, H., *ed.* Oceanography and marine biology; an annual review. London, George Allen & Unwin Ltd., 1963. p. 129-155.
41. OPPENHEIMER, C. H., and L. S. KORNICKER. Effect of microbial production of hydrogen sulfide and carbon dioxide on the pH of recent sediments. Publications of the Institute of Marine Science, University of Texas, 5:5-15, 1958.
42. RICHARDS, F. A., and R. F. VACCARO. The Cariaco Trench, an anaerobic basin in the Caribbean Sea. *Deep-Sea Research*, 3:214-228, 1956.
43. EMERY, K. O. Source of water in basins off southern California. *Journal of Marine Research*, 13(1):1-21, 1954.
44. EMERY, K. O. The sea off southern California. New York, John Wiley & Sons, Inc., 1960. 366 p.
45. ZOBELL, C. E. Occurrence and activity of bacteria in marine sediments. *In* Trask, P. D., *ed.* Recent marine sediments; a symposium. Tulsa, Okla., American Association of Petroleum Geologists, 1939. p. 416-427.
46. MOORE, H. B. Marine ecology. New York, John Wiley & Sons, Inc., 1958. 493 p.
47. CHAPMAN, V. J. Seaweeds and their uses. New York, Pitman Publishing Corporation, [1949]. 287 p.

APPENDIX D.

WASTE DISPOSAL IN THE MARINE ENVIRONMENT—A LITERATURE REVIEW

Environmental effects of marine disposal of solid and liquid wastes from barges and other vessels may be divided into physical and chemical aspects, biological aspects (including public health) and their interrelationships.

At present, we have a theoretical understanding of mixing and diffusion phenomena which tells us where the waste material should go. In addition, we have a rudimentary understanding of the probable effects of a given waste concentration on certain organisms. By contrast, we have only a very limited understanding of how the waste actually disperses and how the ecosystem actually responds to the presence of the pollutant.

A series of carefully conducted laboratory bioassay tests is generally the first step in defining the level of dilution that is safe for a given set of conditions. Unfortunately, there are significant problems associated with achieving successful test results, and there are more difficult problems associated with effective prediction of the actual mixing or diffusion rate to be expected at the disposal site.

The broader aspects of oceanic circulation were discussed in Appendix C, as are the marine ecological interrelationships generally known as the food chain. More detailed considerations are presented below.

WATER QUALITY REQUIREMENTS

A water quality standard is a plan established by governmental authority as a program for water pollution abatement, and includes water use classifications, water quality criteria necessary to support these uses, and a plan for implementation and enforcement. Water quality criteria are the scientific requirements on which a decision or judgement may be based concerning the suitability of water quality to support a designated use.[1] In essence, water quality criteria are the parameters or measuring sticks used to evaluate whether the specified water quality standards are being met.

The Federal Water Pollution Control Act, as amended by the Water Quality Act of 1965,[2] authorized the States (and the Federal Government) to establish water quality standards for interstate (including coastal) waters. Specific guidelines for the establishment of these standards are contained in the Act. If a given State fails to adopt standards consistent with these guidelines, the Secretary of Interior is authorized to develop the necessary water quality standards for the body of water in question.

Water quality criteria for the coastal waters (extending out to 3 miles) have been established by most coastal states. There are no water quality criteria for waters beyond the 3-mile territorial limit of the United States. Where they exist, these criteria are generally of a descriptive nature, and specific allowable waste concentrations and other quantitative measures are rarely included. Exceptions to this are the several California State Water Quality Board Resolutions which specify limits for such measures as pH, dissolved oxygen, and waste concentration at given distances from the waste disposal barge.

Water quality standards and criteria depend upon the beneficial uses of the water, which for open coastal waters include: (1) propagation of fish, shellfish, and other marine life; (2) boating and navigation; (3) esthetic enjoyment; (4) commercial and sport fishing; (5) skindiving; (6) transport, dispersion, and assimilation of wastes; (7) bathing. The relative importance of these beneficial uses varies geographically and seasonally. In considering the level of water

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quality required for the various uses by marine life, man, or industry; water quality criteria are typically defined on the basis of physical, chemical, bacteriological, or biological characteristics or parameters.[3] Many of these same parameters are used in research studies designed to assess the probable effects of waste discharge in marine waters.

PHYSICAL PARAMETERS

The principal physical parameters include color, odor, turbidity, particulate matter (i.e., floatable and suspended solids), transparancy, salinity, temperature, and density of the water column (which is a function of temperature and salinity). Also included are hydrodynamic characteristics such as eddy diffusivity, and geological characteristics such as the composition, grain size, and distribution of bottom sediments.

As McKee has pointed out, physical parameters are most often used to assess the changes that take place in well-defined environmental relationships as a result of the addition of potential pollutants.[3] For example, the addition of waste material contained in large volumes of fresh water media will alter the horizontal and vertical salinity distribution. This will in turn change the existing vertical stability of the water column, which could have a direct effect on the ultimate mixing of the wastes.

There is a substantial body of published work dealing with general problems of mixing, diffusion, and dispersion in marine waters and in related topics (in particular see Orlob, Okubo, and Foxworthy.[4-6]

Numerous factors control the dilution and dispersion of the waste, including such large-scale oceanographic features as density distribution, permanent currents, and tides, as well as local morphology, wind currents, mass transport, and wave action.

In general terms, currents move the water mass containing the waste field away from its point of origin while dilution and dispersion of the waste field take place more or less contemporaneously. When waste material is discharged at sea, components heavier than sea water sink and the lighter fractions float. Dispersion or lateral spreading of the waste is a function of the sinking rate of that waste, and the interaction of forces producing lateral movement. The nature of the sinking action depends on whether or not the waste is a solid or a liquid.

Solids sink (or settle) according to Stokes' law[7] except for modifications introduced by the hydrodynamic shape of the body or particles, and the horizontal forces of currents. The behavior of solids with densities (or bales of solids with composite densities) close to that of sea water is somewhat more complex and need not be discussed here.

Liquid wastes discharged in sea water are diluted and dispersed by the initial dilution of the waste, and subsequent dispersion of the diluted waste field. The denser components of the liquid sink with some attendant dispersion until they encounter a density level in the water column equal to their own. At this depth, a submerged waste field forms with subsequent mixing and lateral dispersion according to isentropic principles.[8] For the components with densities close to sea water, mixing and dispersion take place predominately in the surface water layer under the influence of turbulence produced by winds, waves, currents, and the passage of the disposal tug and barge.

For engineering purposes associated with the disposal of wastes at sea, the turbulent mixing phenomenon or eddy diffusion is best approximated by a modification of Fick's Law,[9,10] which holds that the turbulent mass transfer of a property of a fluid (i.e., temperature, salinity, etc.) per unit of time is proportional to the average concentration gradient. The proportionality constant is called coefficient of eddy diffusivity; it is not a physical constant but depends on the nature of the turbulent motion.

Since the coefficient of eddy diffusivity is fundamental to an accurate understanding of mixing, considerable attention has been given to the determination of the appropriate value of this coefficient for various mixing situations found in the ocean. Most investigators have limited their studies to the horizontal component of eddy diffusivity in the surface layer of the sea.

Pearson and Orlob each assembled values of the eddy diffusivity coefficient obtained by several investigators;[9,4] the broad range of values (between 10^4 and 10^6) has caused several investigators to suggest that the Fickian equation may be an inadequate model for completely describing eddy diffusion processes.[5,6]

Although there has been considerable disagreement in the literature on how to formulate a diffusion law adequate to describe oceanic mixing processes, it is generally evident from the values summarized earlier and in more recent work[11] that the magnitude of the eddy diffusion coefficient increases greatly with the scale of the disturbance being considered. For further discussion, the reader is referred to the references cited.[9,4,11]

Specific studies of the mixing of barge-delivered waste in the sea suggest that mixing and diffusion of wastes generally takes place rapidly in the wake of the disposal barge.[12-14] This mixing is hastened by the added turbulence associated with the passage of the tug and barge and the pumped discharge of the waste. The precision of the diffusion coefficients calculated from studies of various disposal operations is somewhat doubtful because it is difficult to distinguish between the natural diffusion of the waste and that induced by the barge effect just mentioned. From the experimental work at sea, it was estimated that the effect of the barge was to increase average mixing rates by a factor of three,[13] although stirring by the barge produced highly irregular patches of relatively undiluted waste, which is in agreement with the description of the mixing process presented by Eckart. How long these discrete patches may retain their identity is not known, but is is probably on the order of 3 to 4 hours. Hood, Stevenson, and Smith emphasized that the actual pattern of diffusion in the wake of a barge will be understood only through additional experimental work at sea.[15]

In connection with studies of the disposal of paper mill wastes off the Texas coast, Hood and Abbott developed a predictive equation for diffusion.[16] Using this equation, good agreement between the predicted and observed waste concentration in the wake of a chlorinated-hydrocarbon disposal barge 5 minutes after discharge were obtained.[13]

CHEMICAL PARAMETERS

The chemical measures used in defining water quality criteria were summarized by McKee.[3] They include: hydrogen ion concentration (pH); dissolved gases (oxygen, carbon dioxide, etc.); chlorinity; nitrogen analysis (ammonia, nitrites, nitrates); organic carbon (COD) and total carbon; biochemical oxygen demand; nutrients (phosphates, nitrates, silicates, etc.); heavy metals (copper, lead, zinc, etc.); oily substances (hydrocarbons of industrial origin); trace organics (pesticides, detergents, etc.).

In the past, determinations of most of the foregoing chemical measures have resulted in only microquantities for which the effects on beneficial uses are difficult to establish. Chemical analyses of the bottom sediments have, however, often proven useful in assessing the overall impact of pollution, owing to the integrating characteristics of sedimentation and biological accumulation. Generally, the first seven parameters establish the numbers of organisms which are found in the marine environment. The last three may be more critical, for they may either preclude the existence of any life or may so alter the ecosystem that only undesirable forms can survive. It is these compounds whose biological effects must be characterized.

BIOLOGICAL PARAMETERS

In a highly simplified way, the biological assemblage in the sea can be subdivided into three zones: the flora and funa which live in the surface and near surface (euphotic zone) waters; the assemblage living in the mid-water zone; the bottom (or benthic) dwellers.

The surface and near-surface waters are by far the most heavily populated zone; phytoplankton abound and the fauna range from the microscopic zooplankton up through the food web to the large fish and mammals. Within this zone the greatest concentrations occur in relatively shallow coastal waters; these concentrations include our commercial and sport fish as well as sharks, seals, and whales. Also found at the surface are seasonal concentrations of fin fish and shellfish larvae that spawn in open water to return later to near-shore and bottom waters.

The mid-water depths (or mesopelagic zone) are characterized by a low animal population. Nearly all the planktonic forms are absent, which results in attendant limitation of the higher orders in the food web. There is a sparse population of nonfood fish and invertebrates such as giant squid, viper fish, anglefish, and octopus.

The bottom or benthic animals are found in somewhat increased numbers relatively nearshore, since the bottom is able to nourish more life than the water column by accumulating all the debris that falls from the surface. Benthic animals can be divided into two basic groups: the epifauna or animals that live on top of the sediments, such as lobster, shrimp, and flounder; and the in-fauna or those living within the sediments, such as clams, worms, and other burrowing organisms.

The principal biological parameters used in defining water quality criteria so as to protect the biological assemblage include: species diversity indices, median toxicity tolerance (TLM) limits from bioassay tests, fish catch statistics, principal species tabulations from plankton and trawl hauls, and measures of primary productivity. Species diversity indices and bioassay tests are becoming increasingly important while the other parameters are less useful in marine environmental control.

Species Diversity Indices

Ecologists have long identified polluted environments with a decrease in the number of species, although the total number of organisms of a given species may increase because of reduced competition. Thus, an examination of the diversity of the organisms in an area may provide a measure as to the general health of the environment. Any organism capable of avoiding the waste field, or which spends a limited portion of its life cycle in the test area, is considered of questionable value as a suitable indicator organism. For this reason, sessile forms or organisms that have little motility (such as bi-valves) are generally used. Stein and Denison evaluated the relative merit of "diversity indices" and concluded that the use of biological indicators are superior to chemical and physical measurements used alone. They strongly emphasize, however, the need for quantitative sampling techniques for the proper development of biological indices for evaluating pollution effects.[17]

Bioassays

The bioassay method consists of preparing a series of test solutions of the waste in water at various selected dilution levels, adding the population of test organisms, and observing their reactions and survival for definite time periods. Certain specifications such as temperature control, number and size of test organisms, volume of test solution, and maintenance of dissolved oxygen are usually incorporated in the test procedures.

Although there are several types of bioassays, two are in general use: (1) the acute static bioassay, in which the test solution is not changed during the duration of the experimen; and (2) the flow-through bioassay, in which the test solution is continually renewed. The advantages and disadvantages of these methods have been discussed by McKee, McKee and Wolf, Hueck and Adema, and Hood, Dube, and Stevenson.[3,18-20] It is generally agreed that the flow through bioassay provides a more realistic appraisal of the actual short- and long-term toxicity of a waste in terms of reproduction and growth; however, because of the requirements for complicated equipment, including metering devices and the provision for a large volume of the waste, this method is not as widely used as the acute static bioassay.

Thus, most of the present criteria for the toxicity of wastes are based on static bioassays conducted for each specific situation according to standard procedure establishment by the American Public Health Association.[21] Toxicity data generally are reported as the median tolerance limit (TLM), which is the concentration of waste that kills 50 percent of the test organisms within a specified time span.

It should be noted that the acute TLM value does not represent a "safe" concentration, as believed by manu, but merely the levels at which half the test organisms are killed. In contrast to acute bioassays, some investigators have conducted bioassay experiments on planktonic organisms, which are interpreted in terms of the concentrations of wastes that inhibit physiological processes (photosynthesis or growth) by 50 percent, rather than the concentration required to cause a 50 percent mortality of the test organisms.[3,17,20] In many cases, significant differences have been found between the acute TLM concentrations and those that are low enough to permit normal reproduction and growth.

To allow for these unknown effects of wastes, the National Technical Advisory Committee on Water Quality proposed that, in the absence of toxicity data other than acute TLM values an "application factor" should be applied to the TLM values in order to obtain permissible concentration of wastes that can be discharged at a given location. The application factor is defined as "...the concentration of a material or waste that is not harmful, divided by the 96-hour TLM value for that material."[1] In practice, very few application factors have been determined for the numerous types of wastes and, as a consequence, the Committee has suggested the use of interim application factors until test data become available. These are given as: 1/100 of the 96-hour TLM for pesticides, metals, and other persistent toxicants; 1/20 for ammonia, sulfides, and other unstable or biodegradable materials; and 1/10 for waste materials with noncumulative toxic effects. When two or more toxic materials that have possible additive effects are present in the same waste, a simple additive mathematical relationship is used to determine the permissible concentration.[1]

REFERENCES

1. U.S. Federal Water Pollution Control Administration. Water quality criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, U.S. Government Printing Office, 1968. 234 p.
2. U.S. Federal Water Pollution Control Administration. Federal Water Pollution Control Act–Oil pollution control act. Washington, U.S. Government Printing Office, 1967. 24 p.
3. MCKEE, J. E. Parameters of marine pollution–an overall evaluation. *In* Olson, T.A., and F. J. Burgess, *eds.* Pollution and marine ecology. New York, Interscience Publishers, 1967. p. 259-266.
4. ORLOB, G. T. Eddy Diffusion in homogeneous turbulence. *Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers,* 85(HY9):75-101, Sept. 1959.
5. OKUBO, A. A new set of oceanic diffusion diagrams. Technical Report 38, Reference 68-6. [Baltimore], Chesapeake Bay Institute, The Johns Hopkins University, June 1968. [51 p.] (Unpublished manuscript.)
6. FOXWORTHY, J. E. Eddy diffusivity and the four–thirds law in near-shore coastal waters. Allan Hancock Foundation Reports 68-1. Los Angeles, University of Southern California, 1968. 72 p.
7. RUBEY, W. W. Settling velocities of gravel, sand, and silt particles. *American Journal of Science,* 23:325-338, 1933.
8. MONTGOMERY, R. B. Circulation in upper layers of southern north Atlantic deduced with use of isentropic analysis. Papers in Physical Oceanography and Meteorology, 6(2), Aug. 1938. Massachusetts Institute of Technology, and Woods Hole Oceanographic Institute. 55 p.
9. PEARSON, E. A. An investigation of the efficacy of submarine outfall disposal of sewage and sludge. California State Water Pollution Control Board Publication No. 14. Sacramento, 1956. 154 p.
10. BROOKS, N. H. Diffusion of sewage effluent in an ocean-current. *In* Pearson, E. A., *ed.* Proceedings of the First International Conference on Waste Disposal in the Marine Environment, University of California, Berkeley, July 22-25, 1959. New York, Pergamon Press, 1960. p. 246-267.
11. LE GROS, P. G., E. F. MANDELLI, W. F. MCILHENNY. D. E. WINTHRODE, *et al.* A study of the disposal of the effluent from a large desalination plant. Office of Saline Water, Research and Development Progress Report No. 316. Washington, U.S. Government Printing Office, Jan. 1968. 491 p.
12. KETCHUM, B. H., and W. L. FORD. Rate of dispersion in the wake of a barge at sea. *Transactions of the American Geophysical Union,* 33(5):680-684, Oct. 1952.
13. HOOD, D. W., B. STEVENSON, and L. M. JEFFREY. Deep sea disposal of industrial wastes. *Industrial and Engineering Chemistry,* 50(6):885-888, June 1958.
14. MACSMITH, W., JR. Offshore disposal of industrial waste. Presented at 42nd Annual Conference, Water Pollution Control Federation, Dallas, Oct. 5-10, 1969. 8 p.
15. HOOD, D. W. The disposal of chlorinated hydrocarbons and other chemical wastes at sea. Fourth disposal operation, June 12-14, 1956. A & M Project 69, Reference 57-20T. College Station, The A. & M. College of Texas, June 1957. 30 p.
16. HOOD, D. W., and W.. ABBOTT. A study of the disposal of paper mill wastes at sea. First disposal operation, June 2-6, 1955. A & M Project 112, Reference 55-42T. College Station, The A. & M. College of Texas, Dec. 1955. 30 p.
17. STEIN, J. E., and J. G.. DENISON. Limitations on indicator organisms. *In* Olson, T. A., and F. J. Burgess, *eds.* Pollution and marine ecology. New York, Interscience Publishers, 1967. p. 323-335.
18. MCKEE, J. E., and H. W. WOLF, *eds.* Water quality criteria. 2d ed. California State Water Quality Control Board Publication No. 3-A. Sacramento, 1963. 548 p.
19. HUECK, H. J., and D. M. M. ADEMA. Toxicological investigations in an artificial ecosystem. A progress report on copper toxicity towards algae and daphniae. *Helgolaender Wissenschaftliche Meeresunters,* 17:188-199, 1968.
20. HOOD, D. W., T. W. DUKE, and B. STEVENSON. Measurement of Toxicity of organic wastes to marine organisms. *Water Pollution Control Federation Journal,* 32(9):982-993, Sept. 1960.
21. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Standard methods for the examination of water and wastewater; including bottom sediments and sludges. 12th ed. New York, American Public Health Association, Inc., 1965. 769 p.

APPENDIX E

LEGAL ASPECTS OF WASTE DISPOSAL AT SEA

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APPENDIX E.

LEGAL ASPECTS OF WASTE DISPOSAL AT SEA

GENERAL STATEMENT

The legal framework governing the disposal of solid waste in marine areas adjacent to the coasts of the United States is unique in its jurisdictional complexities. This is due to overlaps of International, Federal, State and local legal systems, each with corresponding enforcement and regulatory agencies. Claims of jurisdiction and control over the waters adjacent to the coast may not be consistent with claimed jurisdiction over the land submerged beneath it. In effect, it may well be said that no uniform system of law prevails since the purpose, authority, responsibility and enforcement practices of each of the legal systems varies substantially.

The purpose of this chapter is to: (l) outline the international, Federal, and State legal systems, and identify and define their boundaries; (2) discuss the role of their respective regulatory and enforcement agencies; (3) summarize marine waste disposal laws in four coastal States that exercise a measure of control over marine disposal operations. California, New York, Louisiana, and Washington were the states selected.

CURRENT AUTHORIZATION PROCEDURES

The U.S. Army Corps of Engineers, under the direction of the Secretary of the Army, is empowered to permit the discharge or deposit from or out of any ship or barge, any refuse matter of any kind or description "whenever in the judgment in the Chief of Engineers, anchorage and navigation will not be injured thereby," in the navigable waters of the United States (Title 33, United States Code, Section 407 [1964]). Under this authority, the Secretary has exercised jurisdiction and established procedures for obtaining permits for disposal of solid wastes.

The Secretary is also:

> . . . authorized and empowered to prescribe regulations to govern the transportation and dumping into any navigable water, or waters adjacent thereto, of dredgings, earth, garbage, and other refuse materials of every kind or description, whenever in his judgment such regulations are required in the interest of navigation. 33 U.S.C. K 1 (1964).

As a matter of actual practice, application is made to the nearest district office of the Corps of Engineers for a disposal permit. After the Corps consults with local, state or other federal authorities and determines that the activity is not objectionable, rather than issue a permit, a letter of "no objection" is given by a majority of district offices. If objection is found, the letter may be denied.

The difficulty with this procedure is manifold. The letter of "no objection" is not a permit but rather a promise by the Corps that they will not challenge the disposal activities. Furthermore, no other Federal, State or local agency is legally bound by the decision of the Corps to issue a letter of "no objection." Thus, the procedures established do not insulate the disposer from criminal or civil liability.

Limitations on the Corps' authority to issue permits may derive from the definition of "Navigable waters of the United States" found in Title 33 of the United States Code and regulations promulgated thereunder as "those waters of the United States, including the territorial seas adjacent thereto, the general character of which is navigable. . . ." (33

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U.S.C. K 1 (1964), see 33 C.F.R. K 2.205-5 (Supp. 1970)); and as "all portions of the sea within the territorial jurisdiction of the United States, and all inland waters navigable in fact in which the tide ebbs and flows." (33 U.S.C. K 432(c) (1964)). Moreover, the recent case of *Zabel V. Tabb* 296 F. Supp. 764 (M.D. Fla. 1969), held that the Secretary of the Army was not vested with discretionary authority to deny an application for a dredge and fill permit when the proposed construction would not interfere with navigation. It was stressed that interference with navigation must be shown.

Therefore, even though the authority of the Secretary of the Army to prevent obstructions to navigation has been specifically extended to artificial islands and fixed structures on the outer Continental Shelf, 43 U.S.C. K 1333(f) (1964), it has not been extended in any other respect beyond the three-mile territorial zone. Within the zone, interference with navigation must be shown before the Secretary, through the Corps of Engineers may properly deny a permit. The only exception might be based on 33 U.S.C. K 1 (1964) which creates a duty in the Secretary of the Army to prescribe general regulations for the use, administration and navigation of the navigable waters of the United States when public necessity requires for the protection of life and property.

EXISTING LEGAL FRAMEWORK

Few of the laws enacted deal directly with solid waste disposal at sea. The major part of anti-pollution legislation, as well as all international treaties and agreements dealing with pollution are concerned with two separate problem areas: 1) oil pollution in ocean waters; and, 2) pollution resulting from the exploration and exploitation of the natural resources of the sea bed and the subsoil of the Continental Shelf.

The Continental Shelf in a geographical-geological context is the continental land mass, sloping gradually from the low-water line until there is a marked increase in slope to the depths of the sea. Legally, however, it is divided so that the seaward side of the low-water line is the territorial sea (in the United States a three-mile zone bordering the coast). Beyond the territorial sea lie the outer Continental Shelf and the high seas.

International Law

The Continental Shelf harbors vast wealth in the form of oil, minerals, and natural resources. Aware of increased activity on the shore and of advanced technological developments making the exploitation of oil and minerals economically feasible, a Proclamation was issued by President Truman in 1945, stating:

> The Government of the United States regards the natural resources of the subsoil and sea bed of the contnental shelf beneath the high seas but contiguous to the coasts of the United States as appertaining to the United States, subject to its jurisdiction and control (59 Stat. 884, 10 Fed. Reg. 12303 (1945)).

This proclamation was based upon the theory of contiguity and is commonly regarded as the first of any magnitude to deal with the Continental Shelf. It was preceded by the United Kingdom-Venezuela Treaty of 1942, which provided for the division of the sea bed of the Gulf of Paria between Venezuela and Trinidad. This Treaty, however, was not expressed in terms of the Continental Shelf (Grunawalt, *The Acquisition of the Resources of the Bottom of the Sea–A New Frontier of International Law*, 34 Milt. L. Rev. 101, 111 n. 34 (1966)).

The Truman Proclamation made it clear that the character of the high seas, as well as navigation and fishing rights above the shelf were to remain unaffected. The Proclamation is often described as having extended jurisdiction horizontally (See e.g. Note, 6 San Diego L. Rev. 487 (1969)). The justification for the Proclmation was that the shelf was a natural extension of the land mass and the oil and minerals and other resources already claimed in the submerged land to a point three miles beyond the low-water mark oftentimes extended into the outer Continental Shelf. The Proclamation itself did not define the term "continental shelf" but a press release on the same date by the State Department indicated that the shelf was delimited by the 200 meter isobath or depth contour, (13 Dept. of State Bull. 484 (1945)).

Other nations quickly followed suit by claiming jurisdiction and control over shelf areas adjacent to their coasts, but beyond three miles. The claims ranged from declarations of rights in the subsoil, sea bed, waters and the air space above the waters, to declarations similar to that of the United States. The extent of coastal nations' claims to the Continental Shelf caused apprehension in the international community that the freedom of the seas would be unreasonably affected by unilateral acts of coastal nations.

The International Law Commission was authorized to draft a codification of international law in 1949. The four conventions voted upon by the states in attendance at the United Nations Conference on the Law of The Sea, at Geneva, Switzerland, from February 24 to April 28, 1958, were developed by the Commission between 1949–1958.

The 1958 Conference on the Law of the Sea resulted in: (1) The Convention on the Continental Shelf, Sept. 15, 1958 [1964] 1 U.S.T. 471, T.I.A.S. No. 5578; (2) The Convention on the Territorial Sea and Contiguous Zone, Sept. 15, 1958 [1964] 2 U.S.T. 1606, T.I.A.S. No. 5639; (3) The Convention on the High Seas, Sept. 15, 1958 [1962] 13 U.S.T. 2312, T.I.A.S. No. 5200; and, (4) The Convention on Fishing and Conservation of Living Resources of the High Seas, Sept. 15, 1958 [1966] 17 U.S.T. 138, T.I.A.S. No. 5969.

The purpose of the International Law of the Sea Conference and the adoption of the several conventions was to give international legal definition to the claims of coastal states. In this regard, it was agreed that the territorial sea began at the low-water mark. But, the breadth of the territorial sea remained unspecified: "The outer limit of the territorial sea is the line every point of which is at a distance from the nearest point of the base line equal to the breadth of the territorial sea." (Convention on the Territorial Sea, Article 6).

The Continental Shelf doctrine, Shelf Convention, Article 2, proclaimed that the resources of the sea bed and subsoil of the areas adjacent to the coastal state are subject to the exclusive jurisdiction and control of the coastal nation for the purposes of exploration and exploitation. In defining the shelf, the convention agreed:

> The term continental shelf' is used as referring (a) to the seabed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters or, beyond that limit to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas; (b) to the sea bed and subsoil of similar submarine areas adjacent to the coast of islands (Shelf Convention, Article 1).

Thus, the territorial sea begins at an agreed upon point but is unspecified in its breadth. Likewise, the outer limits of the Continental Shelf are defined merely as 200 meters plus the depth of exploitability [200 meters plus X]. The rights of the coastal state over the Continental Shelf were defined as sovereign rights for the purpose of exploitation and exploration (Shelf Convention, Article 2).

Referring to the jurisdiction over the waters, the contiguous zone was defined as a zone contiguous to the territorial sea which "may not extend beyond 12 miles from the base line from which the bed of the territorial sea is measured." (Convention on Territorial Sea and Contiguous Zone, Article 24).

Jurisdiction within this area may be exercised to:

> (a) Prevent infringement of its customs, fiscal, immigrational and sanitary regulations within its territory or territorial seas; (b) punish infringement of the above regulations committed within its territory or territorial seas.

Thus, the jurisdiction exercised over the water area is limited to 12 miles beyond the base line. The boundaries of jurisdiction over the land are as yet imprecise.

The Convention on the High Seas merely reemphasized the freedom of the high seas, which are open to use by all nations, and as meaning, "all parts of the seas that are not included in the territorial sea, or in the internal waters of a state.' (Convention on the High Seas, Article 1).

The failure of the Geneva Conference on the Law of the Sea in 1958 to reach an agreement on several important points, including the breadth of the territorial sea and the extent of fishing rights in the contiguous zone moved the United Nations to convene a second Conference on the law of the Sea in 1960. At the 1960 conference, the United States, in conjunction with Canada, was willing to suggest a territorial sea of 6 miles plus the contiguous zone of 6 miles in which coastal states would enjoy exclusive fishing rights (Second U. N. Conf. on the Law of the Sea. Off. Rec. Nos. 1173 (1960)). The compromise was not accepted and the international legal situation remained the same (*See, The Second Geneva Conference on the Law of the Sea*,54 Am. J. Int'l. L. 751 (1960)).

Current International Law Applicable to Actual Waste Disposal. Although the conventions resulting from the 1958 Geneva conference dealt limitedly with pollution of the oceans, the only international agreement dealing exclusively with the prevention and control of ocean pollution was the International Convention for the Prevention of Pollution of the Sea by Oil. (May 12, 1954, [1961] 12 U.S.T. 2989, T.I.A.S. No. 4900, amended in 1962). This convention creates prohibited zones, generally 50 miles wide, bordering the coasts of all signatory countries in which it is unlawful for any ship, including tankers, to discharge oil or oily mixtures into or upon the sea. The prohibited zones are sometimes expressly stated to be more than 50 miles and in some instances may be unilaterally extended to a maximum of 100 miles by a state which is party to the convention. States are required to take all steps necessary to provide facilities for the reception of residues and oil mixtures from ships in port. The convention is applicable to all ships registered to a contracting government and unregistered ships having the contracting government's nationality, except tankers under 150 tons gross tonnage, other ships under 500 tons gross tonnage, whaling ships, ships on the Great Lakes, and naval ships. Further exceptions are created in case of need to secure the safety of a ship, or prevent damage to a ship or cargo, or to save a life at sea. The United States became a party to theconvention but reserved freedom of legislative action in territorial water, including the application of existing laws (S. Rep. No. 666, 87 Cong. 1st Sess. 1961, U.S. Code Cong. and Adm. News 2395 2398 (1961)). The Convention further required that all ships carry an oil record book which shall list the circumstances, reasons, and date of discharge or escapes of oil or oily mixtures.

Article 24 of the Convention on the High Seas requires the states parties to the convention to promulgate regulations to prevent pollution by the discharge of oil or pipe lines resulting from the exploitation and exploration of the sea bed and its subsoil. The Convention on the Continental Shelf, Article 5, also provides that the living resources of the sea, including the fish, shall not be harmed or interfered with as a result of the exploitation and exploration of the sea bed and subsoil of the shelf. Article 24 of the Convention on the High Seas relates to nuclear or radioactive waste pollution.

Aside from pollution resulting from exploitation of the sea bed and subsoil of the continental shelf or radioactive pollution, the only other sections which might find application would be: Article 2 of the Convention on the High Seas providing that freedom of the high seas "shall be exercised by all states with reasonable regard to the interests of other states in their exercise of the freedom of the high seas;" and, Article 24 of the Convention on the Territorial Sea and Contiguous Zone, which authorized a coastal nation to prevent infringement of its sanitary regulations within its territory or territorial sea, and to punish such infringement when committed within its territory or territorial sea.

Unfortunately, it is unclear whether the sanitary regulations referred to are those enacted to apply to the territorial sea and which may be extended to the contiguous zone, or whether they are regulations applicable within the territorial sea only. The Panel Reports of the Commission on Marine Science, Engineering and Resources state that no domestic legislation presently asserts power to punish an act of pollution occurring beyond the three- mile zone that was in the contiguous zone (Volume 3 Marine Resources and Legal-Political Arrangements for Their Development, Panel Reports of the Commission on Marine Science Engineering and Resources H-87 (1969)). Furthermore, the Secretaries of the Interior and Transportation have recommended in a report to the President, February 1968, that national legislation be amended to assert such a power (Oil Pollution, a Report to the President, A Special Study by the Secretary of the Interior and the Secretary of Transportation, February 1968).

It is interesting to note that Section 18 of Restatement, Second Foreign Relations Law of the United States (1965) provides:

> A state has jurisdiction to prescribe a rule of law attaching legal consequences to conduct what occurs outside its territory and causes an effect within its territory, if either (a) the conduct and its effect are generally recognized as constituent elements of a crime or tort under the law of states that have reasonably developed legal systems, or (b) (i) the conduct and its effects are constituent elements of activity to which the rule applies; (ii) the effect within the territory is substantial; (iii) it occurs as a direct and foreseeable result of the conduct outside the territory; and (iv) the rule is not inconsistent with the principles of justice generally recognized by states that have reasonably developed legal systems. (Quoted in, W. Friedman, O. Lissitzyn and R. Pugh, INTERNATIONAL LAW (1969).

Recently, as a result of the Maltese proposal (U.N. Dec. A./6695, 18 Aug. 1967) for the "reservation exclusively for peaceful purposes of the sea-bed and of the ocean floor, underlying the seas beyond the limits and present national jurisdiction, and the use of their resources in the interest of manking," the Committee on the Peaceful Uses of the Sea-Bed and the Ocean Floor Beyond the Limits of National

Jurisdiction has prepared a number of working papers. Among these, U. N. Doc. A/Ac. 138/7 proposes as a principle that "pollution of the waters of the marine environment, specially radioactive contamination, shall be avoided by means of international cooperation" (*Iden.*, Chap. III (12)). Furthermore, it is suggested that states "shall adopt appropriate safeguards so as to minimize pollution of the seas and disturbance of the existing biological, chemical and physical processes and balances" (Iden) Furthermore, a Report to the Secretary General on Marine Science and Technology, U.N. Doc. E/4487, sets forth the need for international action relating to the prevention of the pollution of the sea.

Realizing that marine pollution is an urgent international concern, the Report nevertheless states that national agreements are supposed to take measures against pollution, leaving as the rule of international organizations "to help governments to obtain the necessary scientific and technical information and also to provide the necessary legal and political framework for reaching such agreements." (*Iden.* at Annex XIV, p. 1).

It is hoped that such agreements may be reached as a result of the Food and Agricultural Organization of the United Nations, Technical Conference on Marine Pollution and its effects on living resources and fishing, to be held in Rome, Italy, on December 9, through 18, 1970.

Current Federal Laws

Through federal legislation dealing with public lands, Title 43 U.S.C. (1964), the United States has extended its legal system for territorial waters to the Continental Shelf:

> The Constitution and laws and civil and political jurisdiction of the United States are extended to the subsoil and sea bed of the outer Continental Shelf. . . .
>
> [T]he civil and criminal laws of each adjacent state. . . are declared to be the law of the United States for that portion of the subsoil and sea bed of the outer Continental Shelf. . . and would be within the area of the State if its boundaries were extended seaward to the outer margin on the outer Continental Shelf. . . . (43 U.S.C. K 1333 (1964)).

Public Lands include:

> [T]he surface and sub-surface resources of all such lands, including the disposition or restrictiion on disposition of the mineral resources in lands defined by appropriate statue, treaty, or judicial determination as being under the control of the United States in the outer Continental Shelf (43 U.S.C. K 1400(g) (1964)).

It is, therefore, necessary to include federal acts relating to public lands even though they were not originally intended to provide for marine areas on the Continental Shelf. It should first be noted that " no single law or regulation deals with all aspects of pollution of navigable waters from watercraft; they are inadequate and ineffective for control of the problem as a whole, although they do provide for control of many of its parts." (Report of the Department of Interior, Federal Water Pollution Control Administration, to the Congress 41, August 7. 1967; 90th Cong. 1st Sess.. Doc. No. 48, Reprint).

The first act dealing specifically with pollution is the New York Harbor Act of 1888 (33 U.S.C. KK 441-451b (1964)). This Act creates authority in the Secretary of the Army to prohibit the discharge or deposit of refuse, dirt, ashes, cinders, or any other matters of any kind, except that flowing from streets and sewers in a liquid state into the harbors of New York, Hampton Roads and Baltimore.

More general in its application is the Rivers and Harbors Act of March 3, 1889, (33 U.S.C. 401 *et seq.* (1964)), which creates authority in the Secretary of the Army to prevent obstructions to navigation in the navigable waters of the United States.

A portion of the Rivers and Harbors Act, known as the Refuse Act of 1899, (33 U.S.C. KK 406-409, 411, 419 (1964)), makes it unlawful to dump refuse matter of any kind, other than that flowing from sewers in a liquid state from any vessel into navigable waters of the United States if navigation would be impeded or obstructed thereby.

In 1924, the Oil Pollution Act of June 7, 1924, (33 U.S.C. KK 431 *et seq.* (Supp. 1970)), was enacted to protect navigation from obstruction and injury by preventing the discharge of oil into the coastal navigable waters of the United States. The Act provided that the Secretary of the Army was empowered to prescribe regulations specifically permitting some discharges into the coastal navigable waters of the United States by vessels. Emergencies imperiling life or property, unavoidable accident, collision or stranding were also excepted from the Act. In 1961, and for the purpose of implementing the International Convention for the Prevention of

Pollution of the Sea by Oil, the Oil Pollution Act of 1961 (33 U.S.C. KK 1001-1015 (1964)), was passed to prohibit discharges of oil into or upon the navigable waters of the United States. Discharges were prohibited within 50 miles of the United States coast line. The Oil Pollution Act of 1961 was amended in 1966, (80 Stat. 372 (1966)), to accord with the 1962 amendments to the International Convention for the Prevention of the Pollution of the Sea by Oil.

The Fish and Wild Life Coordination Act of 1958 as amended (16 U.S.C. KK 661 *et seq.* (1964)), provides in Section 662(a) that:

> [W]henever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, or any public or private agency under federal permit or license, . . .

the United States Fish and Wild Life Service, Department of the Interior, shall first be consulted so as to be able to determine the possible damage to fish and wild life resources with a view to the conservation of wild life resources. Reports made by the U.S. Fish and Wild Life Service,

> . . . shall be made an integral part of any report prepared or submitted by any agency of the federal government responsible for engineering surveys and construction of such project when such reports are presented to the Congress or to any agency or person having any authority or the power by administrative action or otherwise, (1) to authorize the construction of water-resources development projects or (2) to approve a report on the modification or a supplementation of plans for previously authorized projects. . . . (16 U.S.C. K 662(b) (1964)).

This Act read in conjunction with the Rivers and Harbors Act has often been thought to provide a veto power in the United States Fish and Wild Life Service over applications for permits from the Corps of Engineers, Department of the Army for dredging, filling, or otherwise modifying waterways. However, a Federal District Court in the case of *Zabeb v. Tabb* 269 F. Supp. 764 M. D. Fla. (1969), has held that there is no such veto power in the Fish and Wild Life Service.

The purpose of The Submerged Lands Act of May 22, 1953, 43 U.S.C. KK 1301 *et seq.* (1964) as stated in the prologue, (67 Stat. 29,) is:

> To confirm and establish the titles of the states to lands beneath navigable waters within state boundaries and to the natural resources within such lands and waters, to provide for the use and control of said lands and resources, and to confirm the jurisdiction and control of the United States over the natural resources of the sea bed of the continental shelf seaward of state boundaries.

The effect of this Act is to grant title to the lands underlying the territorial waters. That is, the coastal state has title to all lands and resources three miles seaward of the low-water line. An exception is created for states bordering on the Gulf of Mexico. Title is confirmed in those states for three marine leagues or nine geographical miles seaward of the low-water mark. The United States retains rights and powers of regulation and control of the submerged lands beneath the navigable waters for the specific purposes of commerce, navigation, national defense and international affairs. Furthermore, it should be noted that The Submerged Lands Act does not provide for state jurisdiction and control of the waters above the submerged lands. The philosophy of the Act appeared to be to recognize the historic boundaries of the states as they were at the time they entered the Union (1 A. Shalowitz, Shore and Sea Boundaries 125 Coast and Geodetic Survey Pub. 10-1 1964).

The Outer Continental Shelf Lands Act of August 7, 1953, (43 U.S.C. KK 1331 *et seq.* (1964)), is a declaration of the policy of the United States that the subsoil and seabed of the outer Continental Shelf outside the area of lands beneath navigable waters appertained to the United States and were subject to its jurisdiction, control and power of disposition. Again, the character of the high seas, as well as navigation and fishing rights, were to remain unaffected (43 U.S.C. K 1332(b) (1964)). However, 'the Constitution and laws and civil and political jurisdiction of the United States" were extended to the outer Continental Shelf—the subsoil and sea bed—as well as to all artificial islands and fixed structures erected on the outer shelf for the exploration and exploitation, development, removing and transportation of resources "to the same extent as if the outer continental shelf were an area of exclusive federal jurisdiction located within a state. . . ." (43 U.S.C. K

1333(a)(i) (1964)). More specifically, the Secretary of the Army is authorized to prevent obstructions to navigation, (43 U.S.C. K 1333(f) (1964)); the Secretary of the Interior may lease portions of the Continental Shelf for oil and mineral exploitation, (43 U.S.C. K 1334 (1964), 43 C.F.R. K 3380.0-3); and the Coast Guard is authorized to regulate maintenance of artificial islands and fixed structures on the Continental Shelf (33 C.F.R. KK 140-146 (1968)).

The Secretary of the Interior is authorized to prescribe rules and regulations "to provide for the prevention of waste and conservation of the natural resources of the outer Continental Shelf" as well as "to cooperate with the conservation agencies of adjacent states." To delimit the jurisdiction of adjacent states for purposes of identifying its laws and agencies, the President is authorized to determine the lateral boundaries of the state and to project them seaward to the outer margin of the Continental Shelf. Once the boundaries are determined, he is required to publish them in the federal register (1 A. Shalowitz, Shore and Sea Boundaries at 197).

The Federal Water Pollution Control Act of 1961, (33 U.S.C. KK 466, *et seq.*, (1964), was amended by the Water Quality Act of 1965, (Public Law 89-234) and by the Clean Water Restoration Act of 1966, (Public Law 89-753), and has as its purpose to "enhance the quality and value of. . . water resources and to establish a national policy for the prevention, control and abatement of water pollution" (33 U.S.C. K 466 (1964)). This Act sets up the Federal Water Quality Administration now under the authority of the Secretary of the Interior, for the purposes of coordinating activities for the prevention and control of water pollution in cooperation with other federal, state, and local agencies.

The Act enables federal and state funds and energies to be coordinated for the purpose of research and development relating to the prevention and control of water pollution. But further, the Act provides that the "pollution of interstate or navigable waters in or adjacent to any state or states. . . which endangers the health or welfare of any persons, shall be subject to abatement. . . ." Federal enforcement action to abate such pollution shall not displace state or interstate action in that regard. Thus, it provides for state regulation of federally controlled territorial waters adjacent to the coast of states. A proposed law, (R. R. 4148 91st Cong. 1st Sess.), a bill to amend the Water Pollution Control Act, as amended, January 23, 1969, would require marine sanitation devices on all vessels operating in the navigable waters of the United States and would provide that anyone who discharged or contributed to the discharge of oil or any matter into or upon the navigable waters of the United States or adjoining shorelines or beaches, "or into or upon the waters of the contiguous zone" shall notify the appropriate authority. Failure to do so may result in a fine of not more than $5,000.00 or imprisonment for not more than one year, or both. It is an Act of strict liability providing exceptions only for emergency and imperiling life, and for acts of war or sabotage, or for an unavoidable accident, collision or stranding. Civil penalties of not more than $10,000.00 for each offense are also provided. Interestingly, the Act requires that:

> [T]he owner or operator of any vessel who, either directly or through any person, whether or not his servant or agent, concerned in the operation, navigation, or management of the vessel, willfully or negligently discharges or permits or causes or contributes to the discharge of oil or matter into or upon the navigable waters of the United States, or adjoining shorelines or beaches or into or upon the waters of the contiguous zone, (*Iden.* at 12(e)).

shall immediately remove such oil or matter himself. If it is necessary that the United States remove the oil or matter, the owner or operator shall be liable to the United States for the full amount of the costs incurred in the removal. Liability for costs for removals shall not exceed $15 million dollars, or $450.00 per closed registered ton of the offending vessel, whichever is the lesser amount (*Iden.* at 12(d).*

The Solid Waste Disposal Act of October 20, 1965, (42 U.S.C. K 3251 (Supp. 1970)), defines solid waste and authorizes the research and development program for solid waste disposal on land and at sea. Responsibility for mineral and agricultural wastes is assigned to the Secretary of the Interior and the Secretary of Agriculture, and all other solid waste disposal is assigned to the Secretary of Health, Education and Welfare. Research under the Act was to be carried out for a period of four years ending June 30, 1969. The Act however was amended in 1968 to provide a one-year extension of the 1965 Act so as to terminate research on June 30, 1970.

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* *Note added in Proof.* The Federal Water Control Act signed into law in April 1970 postdates the completion of this report and thus its contents are not considered here.

The Water Quality Act of 1965, in reality an amendment to the Federal Water Pollution Control Act, sets forth water quality standards and creates the Federal Water Pollution Control Administration to administer the Act.

The Clean Water Restoration Act of 1966, (Pub. L. 89-753), again an amendment to the Federal Water Pollution Control Act, as well as an amendment to the Oil Pollution Acts of 1924 and 1961, deals primarily with oil pollution and extends the protection from oil pollution to all of the navigable waters of the United States. Further, the Secretary of the Interior with the assistance of the Secretary of the Army, through the United States Corps of Engineers and the Coast Guard, is authorized to administer the Oil Pollution Act.

Federal regulations have been promulgated under the authority of the United States Code and include authorization for the Coast and Geodetic Survey to establish dumping grounds and to prohibit dumping in specified areas on the Continental Shelf. These regulations are found at 33 C.F.R. K 205. Regulations governing all pollution within 50 miles of the nearest land, are found at 33 C.F.R., Subchapter 0. In addition, 9 C.F.R. Section 94.5 prohibits the discharge of garbage containing meats of foreign origin into any territorial waters of the United States, and 7 C.F.C. 330.400, declares that garbage from any conveyance arriving in the United States must be disposed of in such manner as to prevent dissemination of plant pests.

State Laws

The state laws dealing with the regulation of water pollution are variously characterized as laws regarding water quality, conservation, off-shor leasing, health and safety, and public utilities. The laws are applicable to all of the state's inland waters, the sea bed and subsoil of the Continental Shelf, and, under the Federal Pollution Control Act, to the waters of the territorial sea as well. Any disposal of waste at sea occurring in the area between the outer margin of the territorial sea and the low-water mark along the coastline is governed by both federal and state laws.

In order to understand the extent to which some states have legislated in the area of the regulation and enforcement of waste disposal at sea, it will be necessary to specifically examine the laws of several of the coastal states.

California. The final report of the study panel to the California State Water Resources Control Board, March 1969, stated that "the enforcement provisions in the current Water Quality Control Act are totally inadequate." (*Iden.* at 19). Much of the law governing water quality control in California was covered by Assembly Bill 413, effective January 1, 1970. This Act affected large portions of the Water Code, Business and Professions Code, Government Code and Health & Safety Code of the State of California. Under this Act, the legislature found "that the state must be prepared to exercise its full power and jurisdiction to protect the quality of waters in the state from degradation originating inside or outside the boundaries of the state...." (A.B. 4133 K 13000 (1970)). The Act defines the boundaries of the state as extending seaward for three miles. (*Iden.* at K 13200(i)) In addition, the Act held that:

> Any person discharging waste or proposing to discharge waste within any region that could affect the quality of the waters of the State. . . and any person who is a citizen, domiciliary or political agency or entity of the State discharging waste or proposing to discharge waste outside the boundaries of the State in a manner that could affect the quality of the waters of the State within any region, shall file with the regional board of that region a report of the discharge, containing such information as may be required by the board. (*Id.* K 13260(a)).

Additionally, it is stated that "nothing in this section shall limit the power conferred by this chapter to regulate the disposal of waste into ocean waters beyond the boundaries of the State." (*Id.* at K 13200). The Act is to be administered by the State Water Resources Control Board which is divided on a regional basis into nine separate water quality control boards.

New York. In New York, classifications and standards of quality and purity for New York State are set forth in Part 700-703, Title 6, Official Compilation of Codes, Rules and Regulations, November 1968, (Pamphlet, Classifications and Standards of Quality and Purity for Waters of New York State, Waters Resources Commission, New York State, Department of Health, November 1968). The standard of quality and purity varies according to the use and the source of the water supply which is being regulated. These classifications and standards are enforced by the New York State Department of

Health. In addition, New York is a member of the Tri-State Compact between New York, New Jersey and Connecticut (Tri-State Compact for Pollution Abatement, Interstate Sanitation Commission, New York, New Jersey, Connecticut, (1936)). The Compact sets up the Interstate Sanitation Commission for administrative purposes and provides:

> Each of the signatory states pledges each to the otehr faithful cooperation in the control of future pollution and agrees to provide for the abatement of existing pollution in the tideland and coastal waters in the adjacent portions of the signatory states. . . . (Tri-State Compact at 7, Article XI).

New York also provides for the issuance of permits for dmas, impoundment structures, artificial obstructions, docks, piers, and wharfs. These permits are issued by the Water Resources Commission and may be denied if the health and welfare of the people of the State or the natural resources, including soil, forest, water, fish and aquatic resources are likely to suffer from any such construction or modification. However, before the permit may be denied, a public hearing in connection with an application for a permit must be provided (N.Y. Water Resources Code K 429). New York Water Resources Commission, Part 611, Rules and Regulations, Issuance of Permits under Conservation Law, Article V, Part III - A, Sec. 429, as amended March 20, 1967, sets forth the procedural requirements for the issuance of a permit, objecting to the issuance of a permit, and hearings before the commission on the question of permit issuance.

Louisiana. In the State of Louisiana, Water Quality Standards were promulgated in 1968, by authority of 56 L.R.S. K 1439. These water quality criteria were to be applied to the streams, coastal waters, and streams discharging into coastal waters of the State of Louisiana. (Water Quality Criteria and Plan for Implementation, State of Louisiana, Louisiana Stream Control Commission, 1968)

Insofar as the coastal waters are concerned, the Stream Control Commission anticipates that the coastal waters shall be used to carry treated municipal and industrial wastes and sets forth as a general criteria:

> No wastes after discharged to the coastal waters shall create conditions which will adversely affect the public health or use of the waters for propagation or aquatic life, recreation, navigation, or other legitimate uses not prohibitied by high natural mineral content. (*Iden.* at 78).

In 56 L.R.S. Section 362, the standard of prohibited pollution in the waters in the State of Louisiana is "any substance which kills fish, or renders the water unfit for the maintenance of the normal fish life characteristic of the waters, or in any way adversely affects the interests of the State." For the purpose of this section, 56 L.R.S. K 355 defines waters as both inland and coastal waters. Application may be made under 56 L.R.S. KK 241-449 for leasing of "water bottoms" of any of the waters of the State for the purpose of oyster cultivation only.

Washington. The discharge of any matter that shall cause or tend to cause pollution in the waters of the State is prohibited (R.C.W. 90.48.080 (1967)). Permits from the Pollution Control Commission of the State of Washington must be obtained before any disposal of solid or liquid waste materials may be made into the waters of the State (R.C.W. 90.48.160 (1969)), and the permits shall not be valid for more than five years from date of issuance, shall be subject to termination upon 30 days notice and shall be notifiable or subject to the imposition of additional conditions. (R.C.W. 90.48.180-90148.195(1967)).

An example of municipal legislation controlling the pollution of waters and the disposal of waste is the Harbor Code of the Seattle Police Department, Seattle, Washington, authorizing the Port Warden to enforce ordinances prohibiting pollution of the waters of the harbor. Ordinance No. 87983, Sections 43 and 44, prescribes pollution by way of discharge of oil, sunken vessels, watercraft and refuse of all kinds. The ordinance provides that the person discharging oil or refuse shall remove the oil and refuse, and upon failure to do so, shall be liable for payment of all costs of removal by the Port Warden. The payment of the sum or the abatement of a nuisance for discharge shall not excuse the responsible party from prosecution.

AGENCIES INVOLVED IN THE ADMINISTRATION OF STATUTES GOVERNING THE DISPOSAL OF WASTES AT SEA

International Agencies

International agencies concerned with the problems of investigation and control of marine pollution are coordinated under the United Nations Administrative Committee on Coordination (ACC). The groups primarily concerned with the problem are: The Intergovernmental Maritime Consultive Organizations (IMCO): The World Health Organization (WHO): The Food and Agricultural Organization (FAO); The Educational Scientific and Cultural Organization (UNESCO); and, The International Atomic Energy Agency (IAEA) (Report of U. N. Secretary General, Marine Science and Technology; Survey and Proposals E/4487, April 24, 1968, at 83).

> The action now actively under consideration covers the joint provision of scientific and technical advice exchange and dissemination of information and future international legislation for the control of pollution. (*Iden.* See also, Idem at Annex XIV).

Federal Agencies

Various federal agencies are involved in the enforcement and the administration of the federal statutes governing the disposal of waste at sea. The several titles of the United States Code and its sections provide specifically for enforcement of those sections by and through designated agencies. The functions discussion of the specific statutes. Generally-speaking, the jurisdiction of the agencies enumerated in the United States Code extends to the outer boundary of the territorial sea. Beyond that limit on the Continental Shelf, the Constitution, Federal and State laws, have been specifically extended to the submerged land, subsoil and sea bed as well as artificial islands and fixed structures on the shelf by the Outer Continental Shelf Lands Act (43 U.S.C. K 1333 (1964)).

In addition, several federal agencies have assumed regulatory functions over activities taking place on the outer Continental Shelf. These agencies include the Departments of the Army, Interior, Commerce, Transportation, Health, Education and Welfare, and State.

Department of the Army. For example, the Department of the Army, United States Army Corps of Engineers regulates navigation, transportation and dumping into the waters of the outer Continental Shelf (I Public Land Law Review Commission, Study of Outer Continental Shelf Lands of the United States, October 1968). This function of the Corps of Engineers has been extended by the Outer Continental Shelf Lands Act, but only insofar as the regulations and enforcement govern activities of exploration or exploitation of the outer Continental Shelf (43 U.S.C. K 1333(f) (1964)).

Department of Interior. Functions of the Department of the Interior necessarily include some regulation of both the Continental Shelf and the water overlying it. The Bureau of Land Management is empowered to lease portions of the outer Continental Shelf. The United States Fish and Wildlife Service is involved with the policies and procedures necessary to protect and conserve fishing resources. The Federal Water Quality Administration, transferred to the Department of the Interior in 1966, claims regulatory powers over the waters to a distance of 12 miles from the base line to prevent infringement of sanitary regulations. The interpretation of this particular provision of the Convention on the Territorial Sea and the Contiguous Zone providing jurisdiction over the waters is at best inconclusive.

Dealing with conservation and preservation of the land areas of the outer Continental Shelf, the Secretary of the Interior is authorized to prescribe regulations relating to national underwater preserves, such as the Key Largo Coral Reef Preserve (Proclamation No. 3339; 3 C.F.R. 195901963 Comp., p. 71 (1960); 25 F.R. 2352).

Department of Commerce. Under the Department of Commerce, the Environmental Science Services Administration administers the Coast and Geodetic Survey, and the Weather Bureau, both of which are concerned with mapping, charting, warning, prediction, and research. Weather and tide research and prediction, as well as warnings of storms and extreme tides or waves include consideration of the waters overlying the Continental Shelf. However, it does not appear that they have any authority to regulate or enforce disposal of waste in the waters.

Department of Transportation. The United States Coast Guard operates under the Department of Transportation for the purpose of enforcing or assisting in the enforcement of:

> . . .all applicable federal laws upon the high seas and water subject to the jurisdiction of the United States; [and] shall administer laws and promulgate and enforce regulations for the promotion of safety of life and property on the high seas and on waters subject to the jurisdiction of the United States covering all matters not specifically delegated by law to some other executive department. . . . (14 U.S.C. K 2 (1964)).

Department of Health, Education, and Welfare. This department conducts research in marine science activities under the Public Health Service, the National Institutes of Health and the Food and Drug Administration, to determine the effect of pollution, poisons, toxins and diseases on the marine environment, the shellfish and the fish resources.

Department of State. The Department of State operates as a coordinating agency,

> . . .to achieve broadly acceptable international arrangements that will encourage the development and use of the resources of the ocean and that will avoid dangerous conflicts among nations exploiting these resources. (Statement of Herman Pollack, Director of International Scientific and Technological Affairs, Hearings on Implementation of the National Marine Sciences Program before the Subcommittee on Oceanography of the House Committee on Merchant Marine and Fisheries, 90th Cong. 1st Sess., 480 (1967) (*See* 22 U.S.C. K 2556)).

State Agencies

State agencies involved in water pollution control, conservation, solid waste disposal, and health and sanitation cooperate with their respective Federal agencies in the inland waters of the State, and seaward to a distance of three miles from the base line, so as to permit the greatest possible fulfillment of the purposes, regulatory measures, and enforcement practices of both State and federal legislative enactments.

Most States have a designated water pollution control or water quality control board or commission which operates regionally. For example, the San Diego Port Authority has established effective regulations concerning pollution in San Diego Bay and contiguous waters. Although most States have adequate legislation in the areas of conservation and public health and sanitation, few States have specific legislation governing solid waste disposal. Even where solid waste disposal is specifically regulated by state statutes, it is doubtful that the authority to prevent or punish wrongful disposal under the State statutes extends beyond the 3-mile limit. For this reason, it is essential that the State act in cooperation with the Federal agencies, so that even though no specific legislation is in force and effect, the assumption by Federal authorities of jurisdiction over the waters of the contiguous zone can simultaneously implement the purposes and provisions of State laws.

CONCLUSIONS

International law dictates that the high seas shall remain free for the use of all nations, beyond the outer limits of a coastal nation's territorial sea. It has been so stated in international conventions to which the United States is a party.

The Convention of the Territorial Sea and the Contiguous Zone proclaims that a coastal nation shall have limited jurisdiction on the high seas to a maximum limit of 12 miles from the baseline from which the territorial sea is measured (the United States exercises sovereignty only to the 3 mile limit). However, the language is ambiguous, and must be interpreted to accord with a nation's international as well as national policies.

To date, there is no legislative enactment which specifically provides that any agency, department or official of the United States is vested with authority to prevent pollution of the seas from the discharge of solid waste beyond the outer boundaries of the Territorial Sea. Unregulated disposal beyond the three-mile limit can imperil the waters, resources and beaches of the nations. Therefore, specific legislation is imperative if the resources of the oceans are to be protected.

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